# Towards the Improvement of the Musical Experiences of Cochlear Implant Users

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## Declaration

I hereby declare that this thesis, submitted in candidature for the degree of Doctor of Philosophy at the University of Edinburgh, and the research contained herein is of my own composition, except where explicitly stated in the text, and has not been previously submitted for the award of any other degree or professional qualification at this or any other university.

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**Abstract**

Most previous research into cochlear implant (CI) mediated music listening deals with the mechanisms and efficacy of music perception and does not often account for the listeners real-world musical experience. Measurements of music perception ability are based on listening tasks such as pitch-discrimination, timbre-recognition and rhythmic-identification, and rarely (if ever) relate to the individual experience of the human subject. The exploration of musical experience, however, is based on a holistic view of the ways in which individual people experience music, which can be informed by the interaction of a multitude of factors. For the purposes of this thesis, three categories of experience are considered to coalesce to inform the general musical experience: sensory experience, cognitive experience and social/environmental experience.

This thesis moves towards consideration of the real-world musical experiences of cochlear implant users (CIUs) with a view of developing strategies that can be implemented to improve those elements of the musical experience that may be problematic. The thesis comprises three main sections as follows:

The first section investigates the musical experiences of CI users (CIUs) by means of a questionnaire study and the consideration of information gained from music focus groups and conversations with implant users. Results show a great deal of variability in the musical experiences of CIUs but many people report positive experiences of music despite suffering from what may be described as ‘poor’ music perception.

The second section outlines the design, development and implementation of a multi-channel mixer application, which is used in a study exploring the way in which CIUs mix multi-channel music, to gain insight into their experience of musical elements. Analysing the user-generated mix data provides considerable insights into various elements of the musical experience of participants. Again, results show a large degree of variability on this issue amongst CIUs, and also that the average mixes of CIUs differ significantly from that of a control group of normal-hearing (NH) participants.

The third section describes the composition, development and evaluation of a musical work specifically composed for CIUs but designed to be enjoyable for both CIUs and NH audience members alike. The aim of this composition is to promote a positive musical experience by addressing elements of the sensory, cognitive and social/environmental experience based on findings of this research.

This thesis concludes by suggesting that the ideal approach for improving the musical experiences of CIUs should focus on the individual, due to the great deal of variability within this population, and presents some implications of this work and suggestions for future research in this area.

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# Introduction

Over the past twenty-five years, approximately, there have been rapid and significant improvements in the design of cochlear implant (CI) technology which has lead to the acceptance that cochlear-implantation is an ‘effective and safe treatment for deafness’ (McDermott, 2004). Developments in sound processing strategies have led to enormous improvements in the way in which people with hearing losses and profound deafness are able to perceive speech and, in turn, communicate aurally. Approximately 188,000 people worldwide have been fitted with cochlear implants (USFDA, 2009) and the majority report that this technology has benefited their lives greatly (Zeng, 2004). It is, however, common for such people to voice complaints relating to their post-implantation perception of *music*. Tyler et al. (2000) report that 83% of CI users (CIUs) report a post-implantation decline in their musical enjoyment with some users experiencing music as unpleasant, difficult to follow or even painful. Such problems are due, at least in part, to the actual design and construction of these implants and the fact that their intended primary function is to aid speech perception (see chapter 1 for more more specific details). Indeed, it is common for, both professionals and CIUs alike to refer to the processing component of the CI system as the *speech* processor, rather than the more inclusive term of ‘sound’ processor. The mindset signalled by this choice of description, although understandable considering the primary function of cochlear implants, is reported to be particularly frustrating for CIUs as the appreciation of music via the implant system is the second most commonly expressed desire amongst CIUs (Stainsby, 1997).

There are a number of fundamental differences in the technological prerequisites for the successful perception of speech and of music. In order for speech to be conveyed meaningfully (i.e. to retain the intended meaning of an utterance to a CI user via their implant) it is not essential, in non-tonal languages, for the processed signal to be a precise reproduction of the original signals frequencies, for example. Conversely, the accurate perception of music via the implant system relies on a more precise reproduction of the original signal, including information related to the component frequencies of the signal. In addition, crucial elements of this technology are physically located within the small shell-like structure of the cochlea, a coiled space of approximately three centimetres in length, deep within the auditory system. This not only makes the surgical procedure of complete intra-cochlear insertion of the electrode array difficult but it also means that the *accurate* localised, tonotopic stimulation of the basilar membrane by the electrode array is far less accurate than in normal hearers (see chapter 1 for further details). This, coupled with other technical issues relating to the way in which the CI system processes sound, impacts on the music perception abilities of CIUs, particularly with regard to pitch discrimination and in turn melody recognition, and also timbre recognition (Gfeller et al., 2002a & b), for example. Conversely, the beat and rhythmic elements of music are often reported to be well perceived by CIUs and studies (Gfeller et al., 1998; Kong et al., 2004; McDermott, 2004) show that CIUs show rhythm perception which resembles that of normal hearing control subjects.

Despite the problems associated with CI-mediated music perception, many CIUs report positive experiences of music in some respect and it is this important fact that I wish to build on throughout this thesis. A growing body of literature exists (see chapter 1) which relates to the music perception abilities of CIUs which is extremely important and valuable as it has lead to a wide understanding of the way CIUs hear and perceive music, generally and with regard to specific elements of music. Such research may also lead to developments in implant design or sound processing strategies, for example.

In this thesis, however, I will take a different approach and will consider real-world musical *experiences*, something which I believe to be different to but potentially encompassing the music *perception* abilities of CIUs, with a view towards developing strategies that can be implemented to improve those elements of the musical experience that may be problematic. My focus on musical experiences will take a holistic view of the ways in which individual people experience music, which can be informed by the interaction of a multitude of factors which are (for the purposes of *this* thesis) divided into three categories of experience, namely: sensory experience, cognitive experience and social/environmental experience (see chapter 1).

## Aims of Thesis

The aims of this thesis are threefold:

1. To gain an understanding of the musical experiences of CIUs.
2. To use this knowledge to compose music specifically designed to suit the listening needs of CIUs.
3. To develop and test a software system that will allow individual CIUs to tailor the sound of recorded (mulit-channel) music to a way that suits them best, based on their *individual* preferences and needs.

## Scope of the Thesis and Original Contribution to the Field

This thesis has been approached from the perspective of a musician/music student and, therefore concentrates on *musical* issues relating to the area of 'cochlear implants and music', as opposed to issues relating to implant technology or audiology, for example. The original contribution of this thesis lies in three main areas:

1. A investigation into the real-world *musical experiences* of CIUs.
2. The development of an easy to use multi-channel mixer application which facilitates the manipulation of multi-channel music in order to create unique 'mixes' tailored by and for the user. This mixer is specifically designed to work with 6-channel audio and outputs the parameters of the mixes (for analysis purposes) upon completion.
3. The development of a composition written specifically for CIUs, aiming to be enjoyable and comprehensible for both CIUs and NH audience members alike.

## Thesis Structure

### Chapter 1: Literature Review and Contextualisation of the Thesis

This chapter fulfils three main roles which serve as an introduction to the rest of the thesis due to the multidisciplinary nature of this work. Firstly, a basic overview and comparison of the normal and the implanted auditory systems are presented in order to outline this issue and the fundamental differences that exist between them. Secondly, a number of basic, yet important, musical issues are explored and disambiguated and a summary of the relevant literature on cochlear implants and music is presented by way of outlining the pre-existing work in this research area.

This chapter concludes by discussing the nature of musical experience and presents a theoretical framework which is proposed, for the purposes of this thesis, as a way to consider the coalescence of many factors which can be categorised by three separate areas of experience, namely sensory, cognitive and social/environmental.

**Chapter 2:**

This chapter outlines work that was conducted during an internship at the Hearing Rehabilitation Foundation in the summer of 2007. This includes the planning and running of a music focus group for adult CIUs and a four-day music workshop for paediatric CIUs. Work conducted during this period was particularly useful in the formation of ideas that would inform the focus and content of this thesis.

**Chapter 3:**

Chapter three presents results from a self-administered questionnaire study that was conducted as the first formal step in an investigation into the musical experiences of CIUs in Scotland. This study was designed in reaction to previous studies in this area which tend to focus on music perception and rarely consider the musical experience (as discussed in chapter 1), thus the results of previous studies in the field, although extremely valuable, were not sufficient for the purposes of *this* work.

Results from this study show that in general, there is a significant decrease in the elective music listening frequency of the participants, after implantation. Three sub-groups emerge (based on the age at which participants became deaf) and are described as the 'Late Deafened (LD) Group', the 'Pre-Adolescent Deafened (PAD) Group' and the 'Congenitally Deaf (CD) Group'; results show that both the LD and PAD groups show a decrease in their elective music listening frequency and that the CD group shows an increase in the frequency with which they choose to listen to music. Thus, results suggest a connection between the access to memory of NH music listening and evaluation of implant mediated musical experiences.

Many participants choose not to listen to certain styles of music and many do not listen to any music at all. Although this was a commonly reported problem, the causes (i.e. specific instruments or sounds) were not universal, thus highlighting another element of variability amongst participants. Results suggest, despite some difficulties amongst participants with regard to music perception, that the general musical experience is not always regarded as negative and that the ability to engage with and enjoy music (in both consumptive and participatory senses) is something that many participants would like to (re)gain.

**Chapter 4:**

This chapter outlines the design and development of a multi-channel mixer system which is used in the study described in chapter 5. This application was designed to provide users with a simple and easy to use tool to manipulate the sound of complex multi-channel (6-channels, in this case) music using channel-specific gain and filter controls. Another feature of this software which is not found in other applications which provide similar functionality is that users‘ mix parameters are stored in a simple database for analysis purposes.

**Chapter 5:**

This chapter details the study in which the mixer application (see chapter 4) is used. Long term average spectra (LTAS) analyses are used to explore and compare the average user generated mixes of an experimental group of CIUs and a control group of normally hearing (NH) participants. Participants are also questioned about their experience of the music while using the mixer and whether they believe that an application of this nature would be a useful tool in the improvement of their musical experiences.

Results from this study show that the average mixes of CIUs and of NHs, with regard to the Long Term Average Spectra (LTAS) are significantly different and that there are also differences in the musical quality of the mix. This provides support for the idea that these groups have different listening needs, when aiming to create a pleasant and comfortable sound, an important issue to acknowledge if meaningful strategies for the improvement of musical experiences of CIUs are to be developed. A consideration of individual differences, shows that there is a degree of variability in the results of individual participants (particularly amongst CIUs), however, it is unanimously reported that having the ability to manipulate the sound of recorded multi-channel music has led to an improvement in the sound of music and in the general musical experience. Common reports from participants show that it was they felt that they had ‘control’ and a ‘choice’ with regard to the sounds that they heard and that that they would like to have the opportunity to use this programme again. Thus, the opportunity for individualisation is of benefit to CIUs as it allows the creation of a unique, tailored listening experience.

Results generally support current evidence (both anecdotal and otherwise) that CIUs report a preference for music with a strong rhythmic character and that lower pitched musical sounds are often preferred. The positive influence of this application is further supported by the result of a ‘blind’ A-B comparison of two mixes of the same piece of music (one previously mixed by the user and one ‘control’ mix), in which the vast majority of the CIU group stated that they preferred the sound of the mix which *they* had created previously.

**Chapter 6:**

Chapter six describes the composition and development of a ‘musical’ which was specially composed to be enjoyable and comprehensible for CIUs in an attempt to provide positive musical experiences. The work consists of nine pieces of music played by an ensemble of acoustic guitar, cello, drum-kit, bass guitar, saxophone and a male-vocalist (full scores for each piece can be found in appendix G and DVD/CD recordings of the ‘musical’ can be found in H).

A simple questionnaire completed by 22 CIUs (at a performance of this ‘musical’) demonstrates inevitable variability in the responses of participants with regard to many issues such as the relative qualitative ratings of instrumental sounds or the overall sound, for example. An important result drawn from this questionnaire is that every participant except one stated that they would like to attend future musical events aimed specifically at CIUs. This, coupled with written responses from the participants and favourable ratings of musical elements and the ‘musical’ in general, suggests that this was a positive musical experience for many of the audience members.

**Chapter 7:**

The final chapter provides general conclusions which can be drawn from the research and the implications these may have on this area. Additionally, suggestions for future research in this field are also provided.

# Chapter 1

# Literature Review

## 1.1 Introduction

The concept of the electrical stimulation of the auditory system has origins as early as the beginning of the 19th century when Alessandro Volta (the inventor of the battery after whom the the electrical unit 'volt' was named) used a battery as a research tool to demonstrate that electric stimulation could directly evoke auditory, visual, olfactory, and touch sensations in humans (in Zeng, 2004). By placing rods from a 50 volt battery in each of his ears, he observed that, in addition to the muscular shock observed, he was also able to hear crackling as if some 'tenacious paste' was boiling. This experiment was not repeated due to Volta's understanding of the potential danger.

In the 1930's, with the emergence of comparatively modern technology, a group of Russian scientists (Andreev et al., 1935) presented the first direct evidence of electric stimulation of the auditory nerve by reporting that it caused a hearing sensation in a deaf patient whose middle and inner ears were damaged. A number of other efforts reported successful hearing by using electric stimulation in totally deafened patients (Djourno and Eyries, 1957; Djourno et al., 1957a; Djourno et al., 1957b) and this inspired intensive attempts to restore hearing to deaf people in the United States in the 1960s and 1970s (Doyle et al., 1964; Simmons et al., 1965; Michelson, 1971; House and Urban, 1973). From a commercial perspective, however, the House- 3M single-electrode implant became, in 1984, the first device approved by the U.S. Food and Drug Administration (FDA), however the current major cochlear-implant manufacturers are Advanced Bionics Corporation (USA), MED-EL (Austria) and Cochlear (Australia). The cochlear implant has been developed from the single-electrode device that was used mostly as an aid for lipreading and sound awareness to a modern, multi-electrode device that can even allow an average user to talk on the telephone in quiet surroundings. However, despite differences in sound processing and electrode design (discussed below), there appears to be no significant difference in performance among the present cochlear-implant recipients who use different devices (Zeng, 2004).

The purpose of cochlear implants is, primarily, to restore hearing (to some extent) by way of aiding speech perception for those with severe or profound sensorineural hearing losses for whom hearing aids provide no benefit. Currently, most people with modern CI systems are able to comprehend speech using the device alone in favourable listening conditions. This success has led to a situation where CIUs now seek improvements in other areas of their hearing such as their ability to listen to music, for example. As a result, recent years have shown an increase in research which focuses on the CI-mediated perception of non-speech sounds, particularly music. The current thesis is within this vein of research which focuses specifically on music. Much of the current research in this area has explored CI-mediated music perception and the processing abilities of the actual CI systems and, whist acknowledging the importance and impact of this work on the understanding of the music perception abilities of CIUs, this thesis takes a different approach and will be chiefly concerned with the improvement of the musical *experiences* of CIUs, rather than only music perception. This distinction is something which is discussed in depth below.

Gfeller et al. (1997, p.252) suggest that previous studies in the area of CIs and music 'point to several variables that have a probable impact on musical perception and enjoyment of implant recipients'. I propose that the variables noted by Gfeller are a helpful way to outline the issues relating to this area when presenting details on the current research and can be divided into three categories as follows:

1. Technological variables:

   For the purposes of this thesis, technological variables will be deemed as those that relate to the design of the implant, the processing strategy and any other, non-human/non-natural elements and features of the CI system, such as the electrode array and the system's mapping. This is to say that the category of technological variables will refer to the design and functionality of the technological aspects of the implant system.

2. Personal variables:

Throughout this thesis, personal variables will refer to issues that relate to the CIUs regardless of their implant system or any other technological considerations. Such issues may include aspects of their personal history of deafness/implantation, including the duration of pre-implantation deafness, the age at onset of deafness, or even details of their surgery such as array insertion-depth, for example. This will obviously include issues relating directly to the implant system which will be covered by the category of technological variables (as detailed above).

3. Musical variables (referred to as structural by Gfeller, ibid.):

   Musical variables will be defined, throughout this thesis, as anything that contributes to the way that music sounds prior being processed by the implant system. These variables may include details of the actual music such as pitch, harmony, timbre, tempo or orchestration, for example and may also relate to whether the music is live or recorded and sonic issues associated with each of these presentation methods (e.g. mix of recorded sound or physical space of live performance).

   Table 1.1 provides an indication of the types of issues that each category of variables deals with.

| Technological | Personal | Musical |
|---|---|---|
| Type of implant | Duration of deafness | Melody |
| Type of implant | Duration of implant use | Harmony |
| Coding strategy | Prior hearing aid use | Rhythm |
| Electrode mapping | Post-implantation music preferences | Timbre |
| | Training (musical and otherwise) | Instrumentation |
| | | Mix (of recorded audio) |
| | | Live vs. recorded music |
| | | Physical space in which music is heard |

Table 1.1: Variables affecting post-implantation music listening experiences of CIUs

The review of current literature presented in this chapter will be divided into three main sections based on the categorisation of variables, above, which are presumed to impact upon the musical experiences of CIUs. I will begin by briefly discussing the technological variables that have an effect on implant-mediated music listening before considering, in turn, the personal and musical variables affecting the music listening of CIUs. Before discussing these issues, however, I will give a brief and basic outline and comparison of both the normal hearing (NH) auditory system and the implanted auditory system. This will explain the differences between these systems and, in turn, highlight the physiological, and technological reasons for problematic CI-mediated music perception.

## 1.2 The Auditory System

### 1.2.1 Normal Hearers

The auditory system can be considered in terms of three sections; the outer, middle and inner ear. Each section has it's own anatomical features and performs a unique role in the complex process of hearing. In addition, as with any sensory input there is a neurological component in this chain that is ultimately responsible, in this particular case, for the perception of a series of vibrations as sounds.

Sound waves caused by a vibrating body 'travelling through the air' are directed, via the ear canal, towards the tympanic membrane (ear drum). Such waves cause the tympanic membrane to oscillate and, in turn, induce a series of vibrations in the ossicular chain (the three small middle-ear bones; malleus, incus, stapes). The energy in this chain of bones causes the stapes (the final bone in the ossicular chain), to move in a piston like manner that, in turn, creates movement in a membrane in the cochlea known as the oval window. Fluctuations in the position of the oval window provoke pressure oscillations in the cochlear fluid that eventually leads to a wave of pressure along the basilar membrane, which intersects the cochlea along its length, widening from the oval window (base) where it is narrow and rigid towards the apex where it is wider and more flexible. High frequencies produce a wave in this membrane with a maximum near the base of the cochlea where the basilar membrane is stiff and narrow while the maxima of low frequencies are located nearer the apical end of the cochlea where the basilar membrane is wider and more flexible.

The motion induced in the basilar membrane is detected by small hair cells attached to the membrane in the cochlea known as the organ of corti. The fine rods of protein attached to each hair cell (stereocilia) are bent at the base when the basilar membrane moves at the position of the hair cell. This deflection of the stereocilia promotes the release of a chemical transmitter substance (and inhibits this release if bent in the opposite direction). The relative concentration of this transmitter chemical creates or prevents activity in the surrounding neurons that are then relayed to the auditory cortex via the auditory nerve.

Our perception of sound, according to place theory put forward by Helmholtz (1863), depends on the location of the vibration produced by each component frequency of a stimulus on the basilar membrane. Therefore, the pitch of a musical tone is determined by the places where the membrane vibrates, based on frequencies corresponding to the tonotopic organisation of the primary auditory neurons. The term tonotopic refers to the spatial arrangement where sounds of different frequency are processed in the brain. Tones close to each other in terms of frequency are represented in topologically neighbouring regions in the brain. With regard to the auditory system, as outlined below, tonotopy begins at the cochlea. Different regions of the basilar membrane vibrate at different sinusoidal frequencies and the auditory nerves that transmit information from different regions of the basilar membrane therefore encode frequency 'tonotopically'.

### 1.2.2 CIUs

The use of the CI system means that the 'natural', i.e. biological, components of the auditory system, such as the tympanic membrane and the ossicular chain (as outlined above) are bypassed and their function is replaced by an electronic implant system. This system consists of a microphone, processing unit and a transmission coil, (the external parts of the system) and a receiver, stimulator and electrode array, (internal components). It is important to note that there is a degree of variation between CI manufacturers and their products but the following is an outline of the general principals of the implanted auditory system. The microphone detects sound, which is then processed in the system's processing unit (often referred to as the speech processor). The speech processor is the component of the CI system which transforms the sounds picked up by the microphone into electronic signals capable of being transmitted to the internal receiver that relays the information to a stimulator. The stimulator activates the appropriate electrodes in the electrode array as dictated by the signal from the processor as determined by the processing strategy (see outline of coding strategies below) and program parameters for the individual user. [1]

The electrode array is a collection of platinum (or other highly conductive material) electrodes encapsulate in silicone rubber which is inserted into the cochlea. When electrical current is sent to one of the intracochlear electrodes, an electrical field is generated and auditory nerve fibres are stimulated. The functionality of the system is affected by the number and spacing of (active) electrodes in the array. Another issue which has a bearing on the efficacy of this element of the system is the insertion depth, i.e. the extent to which the array has been inserted into the cochlea. The human cochlea is approximately 35mm long and, as noted above is organised tonotopically, however implants do not always reach the apical tip which essentially means that the full length may not be stimulated.

An important point about CI systems, particularly with regard to the perception of music, is the way that the basilar membrane reacts to the detection of frequencies. As was noted above, oscillations of certain frequencies lead to the displacement of the basilar membrane at certain points along it's length; low frequencies lead to displacement waves with maxima in the apical region and high frequencies in the basal region. This, in turn, means that neurons at different points throughout the length of the cochlea respond to and are stimulated by differing frequencies, as in the normal hearing auditory system. It is this tonotopic process that CI systems attempt to model and replicate in CIUs, i.e. basal (i.e. near the base of the cochlea) electrodes are stimulated in order to represent the presence of high frequency sounds and by stimulating electrodes at more apical (i.e. near the apex of the cochlea) positions in order to present sounds with lower frequencies. (Wilson, p.23; in Cooper & Craddock 2006).

As described above, in the normal (i.e. unimplanted) auditory system, the organ of Corti contains between 15,000-20,000 auditory nerve receptors, each with it's own hair cell and movement of hair cells creates an electrical disturbance that can be picked up by the surrounding nerve cells. The brain interprets the nerve activity to determine which area of the basilar membrane is resonating, and therefore what frequencies are being detected. In CIUs (i.e. people who have been implanted due to sensorineural hearing loss) hair cells may be damaged or fewer in number than in the normal hearing auditory system, thus the CI system bypasses the hair cells

[1] Each user's system must programmed individually by an audiologist who sets the minimum and maximum current level output for each electrode in the array based on the user's reports of loudness.

and stimulates the cochlear nerve directly using electrical impulses thus allowing the brain to interpret the frequency of sound in a manner similar to the way it would if the hair cells of the basilar membrane were functioning properly.

However, the electrode array (see below) which stimulates the auditory nerve contains a number of electrodes (up a maximum of 24, depending on the model) meaning that the localised electronic stimulation of the auditory nerve is far less accurate than in the normal auditory system. Electric fields produced by the CI system are comparatively broad and cannot be focused as specifically as the way an inner hair cell can excite a specific auditory neuron but, rather, excites a population of nerve fibers (Drennan & Rubinstein, 2009). Thus, the perception of pitch in CIUs is based on a degraded spatial representation which also, despite having up to 24 separate channels of stimulation, has been shown to yield as few as between 3 to 9 discreet functional channels (Dorman et al., 1997; Fishman et al., 1997; Friesen et al., 2001). Additionally, depending on the model of implant, the efficacy of the surgery and the health of the cochlea the electrode array may not cover the full length of the cochlea meaning that certain areas of the cochlea may not be stimulated or, if so, stimulated in an inaccurate manner.

With this in mind, and given the differences in the technical prerequisites for the successful perception of speech (that which the implant is primarily designed to process) and music (see below), it is clear that the CI systems face various problems in the accurate processing of music due to a number of technological issues (as described above). Other issues and considerations regarding the efficacy of the implant system with specific focus on post-implantation sound perception and music listening experiences are outlined below.

## 1.3 Music

It is important to give a brief introduction to some fundamental musical concepts for the purposes of clarity throughout this thesis. Therefore, I will briefly outline a number of musical issues which will be be pertinent throughout the thesis.

### 1.3.1 Pitch and Frequency

I has been suggested that since the same notated music can be played with varying loudness (loudly or softly) and on different instruments (with distinct timbre characteristics), pitch appears to be the '... most fundamental of the musical attributes of a tone' and that it depends on measurable and describable properties of the 'corresponding vibration' (Campbell & Greated, p70). Roederer (1995, p15) refers to vibration as, for example, the characteristic type of motion of the eardrum when we hear a sound that is caused by pressure oscillations in the ear canal. Such pressure oscillations are '... associated with an incoming sound wave' which is created by the vibratory motion of a body. Pitch, therefore, can be considered as a musical attribute of a tone that is based on our perception of the frequency of such a vibration; or put another way, pitch is a purely psychological construct that relies on our perception of the frequency of vibratory motion.[2]

With regard to our perception of the musical characteristics of a tone, only those vibrations that have a periodic character 'generate sounds with a strong sense of pitch' (Campbell & Greated, p11). This is not to say that only periodic vibrations can cause pitched sounds, in fact, the majority of musical 'sound generators are not strictly periodic vibrators'. It is noted that those vibrations that are periodic or, at least in part periodic by nature are those, which are recognised as having pitch and are described as tones. The terms 'tone' and 'note' refer, in an abstract sense, to the same thing, however, 'tone' is used for as a description of the acoustical feature noted above, whereas the term 'note' is used to describe that which is seen on a musical score or discussed by musicians, for example.

In contrast, those vibrations that are non-periodic by nature are described as noises. This does not, however, denounce them as unmusical or vibrations that are, in some way, lacking in musical significance as is shown by the example of the noise created by striking a cymbal, i.e. an unpitched sound which is 'generated by non-periodic vibrations' (ibid). This said, it is those sounds that are described as having definite pitch that are the fundamental elements of western tonal music and, therefore, following discussion relates to the connection between the frequency of periodic vibration and pitch.

In order to calculate the frequency of any given event we must count the number of

[2]For the purposes of this chapter, discussion of frequency, vibratory motion and other related terms pertain only to musical instruments unless otherwise stated.

occurrences of the said event within a specific period of time and then divide this number by the length of the time interval in which we were measuring the event occurrence.

This relationship is expressed by the following equation:

$$f = 1/T$$

When referring to musical vibrations (as opposed to the vibrations which we perceive as non-musical sounds), common practice is to measure the number of vibrations within the time interval of 1 second and the generally accepted unit of frequency is the hertz (Hz).

In written musical notation, the pitch of a note is indicated by the vertical position of it's head (generally the rounded part) on the stave, a construct of 5 main horizontal lines (which can be extended above or below as necessary depending on the pitch of the note) and can be thought of as a graph of pitch (plotted vertically) against time (plotted horizontally). The names of the notes (pitches) are named, in English speaking countries, after the first seven letters of the English alphabet, namely; A, B, C, D, E, F and G, however, it is obvious (consider a piano keyboard, for instance) that there are more notes than there are distinct alphabetical names for. The sequence of note names repeats as a result of a phenomenon that corresponds with the perception of the frequency of any tone being doubled or halved. For example, if we hear a tone and then hear a tone with double (or half) the frequency; most (normal hearers) will be able to recognise that the two successive tones are in the particular relationship of octave affinity. This affinity is due to frequency ratio of 2:1 (or 1:2 if the initial frequency is halved, rather than doubled) that we refer to as the octave.

The octave, as described above, is actually divided into twelve equal parts (in modern western music). This division of the octave is a tuning system known as twelve tone equal temperament (12T-ET) and is the most common tuning system in western music. In this system the octave is divided (logarithmically) into twelve parts known as semi-tones.

As with the pitch interval of an octave in which we notice a frequency ratio of 2:1, we are able to state similar rules for other intervals within the 12-TET tuning system. The frequency ratio of a semitone within the 12-TET system (ET semitone) is 1.06:1. For the purposes of this chapter, only those mathematical calculations used to determine the frequency of a note will be discussed, those calculations used to determine frequency ratios will be omitted, as they are not necessary in order to understand the connection between frequency and pitch. We are, therefore, able to use the ratio, mentioned above, to calculate the frequency of almost any note based on any frequency; consider the following hypothetical example:

To determine the frequency of the note 1 semitone above one with a frequency of 100Hz, the calculation i as follows:

$$1.06 \text{ x } 100 = 106\text{Hz}$$

In order to find the frequency of the note a semitone above this one (106Hz), we simply multiply the new frequency by 1.06, hence:

$1.06 \text{ x } 106 \approx 112Hz$

Therefore, in order to get from the note we started with to a note that is two semitones, i.e. a tone, above we have the following calculation:

$$1.06 \text{ x } 1.06{:}1 = 2(1.06){:}1$$

Note that when two pitch intervals are *added*, the corresponding frequency ratios are *multiplied*. If applied to the note A (440Hz), we can find the B, a tone above this note in the following way:

$(1.06)2 \text{ x } 440 \approx 494Hz$

This rule can be used to calculate the frequency ratios of larger intervals and therefore the frequencies of notes, given any starting point. Therefore we can use this scheme to calculate frequencies in the following way using A440Hz as a standard reference point:

Using this table, it is possible to work out the frequency of any note in the 12-TET tuning system based on A-440Hz. For instance, if we wanted to work out the E below A-440Hz we would use the following calculation to work out the difference in frequency between the two notes based on their pitch interval. Firstly, we need to work out the frequency of the A below A-440Hz, i.e. an octave lower which we know to be half the original frequency; 220Hz. Secondly, we need to calculate the musical interval between this A (220Hz) and the E above it that we are trying to calculate the frequency of. A to E is a perfect fifth and therefore consists of 7

| ET Semitone increase | Ascending Musical Interval | Frequency Ratio |
|---|---|---|
| 1 | Minor 2nd | 1.06:1 |
| 2 | Major 2nd | $(1.06)^2$:1 |
| 3 | Minor 3rd | $(1.06)^3$:1 |
| 4 | Major 3rd | $(1.06)^4$:1 |
| 5 | Perfect 4th | $(1.06)^5$:1 |
| 6 | Tritone | $(1.06)^6$:1 |
| 7 | Perfect 5th | $(1.06)^7$:1 |
| 8 | Minor 6th | $(1.06)^8$:1 |
| 9 | Major 6th | $(1.06)^9$:1 |
| 10 | Minor 7th | $(1.06)^{10}$:1 |
| 11 | Major 7th | $(1.06)^{11}$:1 |
| 12 | Perfect 8ve | 2:1 |

Table 1.2: Frequency ratios for ET intervals within an octave

semitones. Finally, we need to apply the frequency ratio of $(1.06)^7$:1 in order to find the frequency of a note which has been increased by 7 ET semitones.

$(1.06)^7$ x 220Hz $\approx 330.8Hz$

To recap, *pitch* is a psychological construct that can be viewed as one of the fundamental musical attributes of a tone and is based on our perception of the frequency of a tone's periodic vibrations. *Frequency*, as has been outlined above is an objective measure based on the oscillations of a vibrating body. Pitch, however, is subjective and not measurable; it is a sonic attribute of a sound according to which such sounds can be ordered on a 'scale' from low to high. Sound waves themselves do not 'have' pitch as pitch is not a physical, measurable quantity; their oscillations can be measured to ascertain frequency, but this is not equivalent to pitch which is a subjective *sensation*. It should be noted that, in addition to frequency, pitch also depends (albeit to a lesser degree) on the sound pressure level of the tone. The pitch (*not frequency*) of tones with low frequencies gets lower as sound pressure increases and the pitch of tones with higher frequencies increases as the sound gets louder.

### 1.3.2 Timbre

Timbre is the element of sound by which a listener can differentiate two sounds playing at the same pitch and volume. For example, timbre is that quality which accounts for a trumpet and a saxophone each playing the same note at the same volume yet sounding different. When considering the waveforms of two instruments playing the same note with the same amplitude, the difference in timbre between the two sounds is due, principally, to the differences in the waveform. Although the difference in waveform can account for the difference in timbre, the issue is not quite so simple because many other waveforms will create sounds that are indistinguishable (from the perspective of timbre) from the sounds discussed. That is to say that many notes perceived to have the same timbre can produce many different waveforms. However, the authors state, when considering the harmonic spectra of such notes, that a group of notes with different waveforms can be 'represented with a single harmonic spectrum' (Campbell & Greated, p144).

The quality the sound of a musical instrument is sometimes described in terms of a sum of a number of distinct frequencies in it's harmonic spectrum. The lowest of such frequencies if referred to as the fundamental frequency and other important frequencies in this spectrum are called overtones which may be classed as harmonics (whole multiples of the fundamental) subharmonics (whole divisions of the fundamental) or partials which are those which are not whole number multiples or divisions of the fundamental frequency. For example, if an instrument played the note middle C which has a (fundamental) frequency of 256Hz, the resultant sound is a combination of this frequency and 512Hz, 768Hz, 1024Hz, and so on and it is the relative prominence of these frequencies in the harmonic series that play a major role in the instrument's timbre.

### 1.3.3 Rhythm, Metre, Beat and Pulse

The concept of rhythm is concerned with the understanding of the durational/temporal elements of music. As music is of a temporal nature, it inevitably comprises of elements of various durations which when considered within the structure of the complete work pertain to rhythm. Rhythm can, therefore, be said to refer to the various patterning possibilities for musical duration. The term meter (often confused with rhythm) relates to our comprehension and anticipation of such patterns therefore, use of the adjective 'rhythmic' relates to what might more precisely be described as a metrically regular series of durations and events.

The terms pulse and beat are also often used interchangeably or in place of the term rhythm. Pulse and beat should be considered separately although, in some cases, they may describe phenomena that are closely related or perceptually identical. Consider music 12/8 time as an example; we can say that the music has twelve quaver beats in each bar but it may be common to feel the music (when playing or listening) as having four pulses. Beat is also a term that can be confused with the general idea of rhythm but is generally used as a measurement of rhythmic pulse (see above), i.e. a piece of music in 4/4 time has four beats in a bar. Confusion may arise when we consider that in many pieces of music in simple time, the pulse and beat may be indistinguishable.

### 1.3.4 Harmony

Harmony, with regard to music, is a term that has its origins in ancient Greece and has been applied to different elements of music since, however, by the Middle Ages, the term had developed to describe the *simultaneous sounding* of notes and latterly, the relationships and structures created by such. Modern conceptions of harmony work from the premise that a chord (i.e. the simultaneous sounding of two or more notes) is '. . . primary . . . an indivisible unit' (Dahlhaus, et al., in Grove Music Online). When notes are played simultaneously with frequency ratios of simple fractions the resultant signal will sound consonant (i.e. stable or *'pleasant'*). For example, a note of 100Hz and the note E (125Hz) a major third above it have a frequency ratio of 5:4 and the two notes will have a number of common harmonics. It is, put simply, the combination of simultaneously sounding signals with related fundamental frequencies (simple frequency ratios) and shared or closely related partials that causes the sensation of harmony.

It is, however a common misconception of the term harmony that it relates only to the vertical aspects of music. However, throughout this thesis the term harmony will be used to discuss or describe both the combining of notes *simultaneously*, to produce chords as was outlined above; and *successively*, to produce chord-progressions.

### 1.3.5 Loudness

Loudness is '...that attribute of auditory sensation in terms of which sounds can be ordered on a scale extending from quiet to loud.' (ANSI, 1973). It is the psychological correlate of amplitude (i.e. the physical strength of the signal). Therefore, loudness is something of a subjective measure but is often confused or with other objective measures such as sound pressure level (SPL) or intensity. In fact, the perception of loudness varies on a personal level and is affected by factors other than amplitude, such as frequency and duration of exposure as well as sound pressure.

With regard to the connection between perceived loudness and frequency, it is generally the case that the sensitivity of the human auditory system changes according to the frequency of the stimulus. That is to say that the perceived loudness of sounds with constant intensity levels will change depending on their frequencies. This is illustrated by equal-loudness contours which are a measure of sound pressure (dB SPL), across the frequency spectrum, which a listener perceives pure tones as being of constant loudness to an average young person without significant hearing impairment. The term 'Fletcher-Munson' curves (named after the pioneering researchers in this area) is often used to describe equal-loudness contours however, recent research and developments providing greater accuracy have led to the latter term becoming the most appropriate.

## 1.4 Technological Variables Affecting Post-Implantation Music Perception

### 1.4.1 Implant Design

As discussed above, the cochlear implant is an electronic device, which utilises an electrode array positioned in the cochlea to induce action potentials in the fibres of the auditory nerve that are then transmitted as electrical signals to the auditory cortex where they are perceived as sound (Grayden & Clark, in Cooper & Craddock 2006). Despite the fact that specific designs may differ between CI models and manufacturers, the general working principles are the same (Zeng, 2004). Some elements of the system can be changed without any consequence to the overall functionality of the system such as the shape or colour. A number of other elements of the implant system have an effect on the way that it detects, processes and, in turn, relays sound to the CIU. One minor element, for example is the positioning of the system's microphone. If the microphone is positioned in front of the pinna at the entrance to the ear canal, it is likely to detect a signal that is more similar (acoustically) to that which a normal hearer (NH) would perceive than if the microphone were strapped to the CIU's chest, for example. This is obviously due to the similar position in which the sounds are detected in CIUs and Normal hearers (NHs). Other elements of the CI system that can have a significant effect on the functionality of the system, relate to the design and setup of the electrode array and the processing strategy employed by the systems processor, as discussed below.

### 1.4.2 Electrode Array Processing Strategies

The electrode array is an arrangement of intracochlear electrodes which is surgically inserted into the scala tympani near the round window at the basal end of the cochlea. Structural design and positioning and insertion depth differ slightly between implant models and manufactures but the array is always based around a number of intracochlear electrodes that provide tonotopic electronic stimulation (see above). As was described above, the fact that the electrode array consists of a maximum of 24 electrodes (depending on make/model) means that the tonotopic stimulation of the auditory nerve is far less accurate than in the case of the normal auditory system, something which impacts on music perception abilities such pitch discrimination and timbre recognition, due to their reliance on the processing of frequency and harmonic structure, for example.

It is the case in all current implant systems that the speech processing strategies employed are based on the extraction of speech features including formants or the division of the frequency spectrum of speech into smaller sections which are delineated to provide optimum conditions for speech discrimination (Fearn, 2001). A full explanation of the technological specifications and workings of the implant system would be outwith the scope of this thesis. A basic understanding, however, of the various coding strategies employed by the CI system is important in order to fully appreciate the technical basis of some of the music processing problems of CI systems. The following section will serve as a basic introduction and will, therefore, provide sufficient knowledge of the elementary principals required in order to comprehend the processing strategies currently in use.

**Formant Extracting Strategies:**

By way of introduction to this section it should be noted that the three main broad spectral peaks in a speech signal, created by resonances in the throat and mouth of a speaker (known as formants) are referred to a F1, F2 and F3, the fundamental frequency being named F0 (Fearn, 2001).

**F0F2 and F0F1F2**

The F0F2 strategy is based on the extraction of the frequency within the region of the second formant (ranging from 800 – 2300Hz), which is then used in determining which electrode in the coil should be stimulated (ibid.). Energy present in the range of the first formant is used to determine the rate of stimulation of the electrode.[3] The F0F1F2 strategy is very similar in function to the F0F2 but also encompasses the first formant. The frequency within the range of the first formant is used to determine which electrode will be stimulated in the apical region of the cochlea as this system allows two electrodes to be stimulated based on formants 1 and 2, respectively.

**MPEAK**

The MPEAK (MultiPeak) strategy is an extension of the F0F1F2 strategy but with 3 additional basal electrodes that are devoted to high frequency information.

**Spectral Analysis Strategies:**

**SMSP and SPEAK**

SPEAK is the commercial implementation of the SMSP (Spectral Maxima Sound Processor) strategy. Both strategies use bandpass filters (16 in SMSP and 20 in SPEAK) and calculate the energy in each of the filters (m) and locate and use the filter with the largest energy amplitudes (n) thus essentially selecting the peak. As a result this strategy has become known as an ‘n of m’ or a ‘peak picking strategy’. On the recognition of the filter with the greatest energy, it’s corresponding electrode is stimulated.

**Current Strategies:**

[3] Stimulation rate will not be discussed in any greater detail at this point as it not essential in understanding the basic functioning of the system.

### ACE

The ACE (Advanced Combinational Encoders) strategy, also an ‘n of m’ system could be considered to be an extension of the SPEAK strategy. The main difference between these strategies is that ACE analyses spectral energy.

### CIS

The CIS (Continuous Interleaved Sampling) strategy is designed to stimulate at the highest rate possible and does not use peak selection techniques as in the ‘n of m’ strategies.

### Impact upon Music

Gfeller et al. (1997) conducted a study in which they compared the musical perception of adult CIUs using Cochlear’s Neucleus CI system with two different coding strategies; F0F1F2 and MPEAK (outlined above). Over the period of a year, participants were switched alternately between the aforementioned processing strategies every three months. The performance of the CIUs was evaluated using three measures of rhythmic and sequential pitch processing which were adapted from the tonal and rhythmic subtests of the Primary Measures of Musical Aptitude test (PMMA) (ibid.). Participants were presented pairs of stimuli (in free field) and asked to determine whether the items were the ‘same’ or ‘different’. In the sequential pitch tasks all temporal elements of the signal remained constant with those item pairs that differed varying only in the frequency of one or more of the notes. The rhythmic test contained 14 pairs of short rhythmic patterns with each note presented as C4 (261.63 Hz). Differences between pairs of rhythmic patterns were as a result of varying note duration and participants were again asked to identify whether or not the pairs were the same or different.

Participants also completed a ‘six pulse task’ with stimuli consisting of six pulses of the same duration and frequency (440 Hz) with pauses between each pulse, again, presented to the participant in free field. Four of the pauses were of equal length and one was 10% of the duration of the others (short pause). Participants were instructed to note whether the short pause was at the beginning or end of the pulse pattern.

The results of this study with regard to the perception of structural elements of music are consistent with those previously reported for speech perception (Parkinson et al., 1996; Skinner et al., 1991; Waltzman et al 1992, for example).

That is to say, ‘neither strategy seemed to be clearly superior for either perception of sequential pitch or rhythmic pattern perception’ (Gfeller et al. 1997, p.259). Also, the authors note that the experience gained from the use of one processing strategy may actually improve or assist subsequent performance with another strategy. The authors acknowledge the fact that the two structural areas investigated in this study (sequential pitch and rhythm) are very ‘specific and narrow aspects of music listening’ (ibid. p.259). As the authors point out, narrowly focused examinations of small areas of music perception do not fully represent the way that CIUs listen to music.

Brockmeier et al (2007) explored the impact of different speech coding strategies on the music perception and musical activities of postlingually deafened CIUs using the CIS, ACE and SPEAK coding strategies. This research shows that the self-reported perception of music of CIS, SPEAK, and ACE users did not differ ‘by very much’ [sic.].

As a result of such studies showing little impact on music perception the technical details of coding strategies and implant types, for example, will not be a major consideration in this thesis in favour of focusing on musical experiences.

## 1.5 Musical Variables Affecting Post-Implantation Music Perception

### 1.5.1 Rhythmic Perception of Cochlear Implants

CI users frequently voice complaints about their post-implantation perception of music and such complaints are usually a result of poor pitch perception, which can make music listening a frustrating and confusing experience.

McDermott (2004) outlines that one of the most significant recent research findings in this field is that, on average, CIUs perceive rhythm about as well as normal hearers. This finding is reported by a number of researchers including Gfeller & Lansing (1991, 1992) who found that, with regard to structural elements of music, participants using the ‘Neucleus’ (a model produced by the company Cochlear) implant exhibit more accurate discrimination of simple rhythmic patterns than simple melodic patterns. In addition, it is reported that MED-EL

CIUs described as more ‘appealing’, by way of a subjective rating scale, isolated rhythmic patterns when compared to rhythmic patterns accompanied by a harmonic backing.

This is supported by the results of numerous studies also suggesting that rhythm is the structural element of CI-mediated music that is the most successfully perceived by CIUs. As Donnelly and Limb (2008) point out, when we talk of rhythm we are generally referring to the ‘temporal features of music that typically occur on the order of seconds, as opposed to the fine scale temporal features that occur on the order of milliseconds that are crucial in the perception of pitch and timbre’ (ibid., p4).

Rhythmic information can be extremely important in the recognition of music for CIUs as, diminished pitch, timbre and harmonic discrimination abilities due to inherent problems with CI technology may render temporal cues as one of the only discernible factors in music recognition. Indeed, a common finding that is often supported by anecdotal evidence from CIUs is that rhythmic information can be key to the recognition of familiar music and can be of greater importance to a CIU than pitch cues. Gfeller et al. (2002), in a study probing the abilities of CIUs to recognize familiar melodies, found that the majority of the melodies that were correctly identified had a highly memorable or remarkable rhythmic line. This would suggest that participants were, at least in part, using temporal cues to inform their identification of the music, thus, melodies with a unique, interesting or memorable temporal component were more readily identified.

Similarly, a study by Kong et al. (2004) used two different versions of songs that were familiar to the participants as the experimental stimuli. The first version was the melody played in its original form, i.e. temporal and pitch information was unaltered. The second version was the melody played in a way that preserved the melodic contour of the piece of music but was altered so that the duration of each note was standardized thus eradicating any temporal cues. The results of this study show NH participants attaining almost perfect scores for both versions of the stimuli. However, the CIUs, despite identifying approximately two-thirds of the first-version pieces of music, performed very poorly when attempting to identify the second-version pieces of music (those which retained the melodic line but which had equal note duration). Results such as those presented above serve to reinforce the idea that rhythmic information is one of the structural elements of music that CIUs rely on most in order to recognize music.

Leal et al. (2003) also use a discrimination and identification paradigm in order to test the rhythmic perception of CIUs. This study differed from most others in that the results of the CIUs were not directly compared to that of NH participants but were actually compared with their own performance in a speech-perception task. Subjects were presented rhythmic pairs of stimuli, one of which may differ from the other in note duration or intensity. In this case, subjects were asked to determine whether each item in the pair were the 'same' or 'different' and also to identify the point at which the two pieces differed, if at all. 59% of the CIUs tested in this study were able to determine whether the pieces were the same or different and 41% were able to identify the point at which the pieces differed. When compared to the results of the speech perception task, the authors note that approximately two-thirds of the subjects who were successful in the first (rhythmic) task achieved a score in excess of 90% on the speech perception measure.

Kong et al. (2004a) conducted a study that was somewhat unique from the majority of studies dealing with the rhythmic perception abilities of CIUs. In this study, participants were asked to discriminate relatively subtle changes in the tempo of the music. Pairs of rhythmic patterns were used as stimuli, one of which was played at 60, 80, 100 or 120 beats per minute (BPM) and the other was played slightly faster. Results show that although NH subjects performed marginally better than CIUs overall, there was no significant difference in performance between the groups. In addition, the tempo of the stimuli made no significant difference to performance on this task.

The authors also tested the ability of both NH and CIU participants to identify the corresponding notation of a heard rhythmic pattern (from a choice of seven) with a duration of 4 beats. In each rhythmic pattern, the second beat consisted of various permutations of crotchets, quavers and semiquavers and beats one, three and four were all played as crotchets. This test showed a greater difference between the experimental groups with NH subjects achieving scores of close to 100% and CIUs approximately 75%.

### 1.5.2 Pitch Perception of Cochlear Implants

As mentioned above, the cochlear implant was initially invented and developed as an aid for verbal communication and is therefore designed to focus on the transmission of the acoustical parameters deemed most salient for successful speech perception. As a result, it is now the case that a great deal of CIUs score highly for word/sentence recognition and accuracy on open set speech perception tests (Gfeller, 2000). This accuracy is, however, in contrast to the perception and discrimination of pitch by CIUs (Gfeller & Lansing, 1991, Looi et al., 2004, for example) and is unfortunate if we consider the premise that melody is one of the fundamental elements of many forms of music.

Peter Kivy (2002), states that 'A melody is individual tones heard as a continuous and connected whole.' Theoretically speaking, if we accept Kivy's definition of a melody, and if CIUs experience difficulty in the perception and discrimination of pitch, then CIUs are unlikely to be able to accurately recognise individual tones and, in turn, perceive melodies as continuous, connected wholes. That is to say that the perception of melody will be greatly hindered by the potential inability of CIUs to accurately perceive some of the components (individual frequencies) of a melodic structure.

A study conducted by Looi et al. (2004) tested the relative abilities of postlingually deafened CIUs and NH subjects to discriminate pitch and recognise melodies. Pitch discrimination (pitch ranking) was investigated by playing recordings of trained male and female vocalists singing vowels sounds separately at two different pitches. Participants were asked to indicate which note they believed to be the higher pitch (not volume) and were also played 15 melodies (rated as familiar prior to testing) and were asked to name the music.

On both tests, CIUs performed significantly worse than NH subjects. CIUs were unable to accurately and reliably rank pitch difference in terms of higher and lower within a 25% of an octave (three semitones/minor 3rd). Within 50% of an octave (six simitones/tritone), CI users performed better than chance yet still significantly lower than NH subjects and within 1 full octave (12 semitones) there was a 68% success rate. The results of the melodic identification task support the suggestion that such difficulties and inaccuracies relating to pitch ranking have a negative effect on melody recognition as CI users displayed only a 51% success rate when identifying familiar melodies compared to 98% by NH Subjects. It is also noted that CI subjects had greater difficulties with the identification of music that was rhythmically simple or sparse  this may be due to the fact that temporal cues were perhaps less obvious or memorable.

Although melody can be considered as one of the fundamental building blocks of music and in many cultures and musical traditions is deemed to be central to the essence of music, it is completely unfair and misleading to consider the terms ‘melody’ and ‘music’ to be synonymous. To do so would render as meaningless the extensive variety of musical devices and components that unite and coalesce in order to create the rich and complex phenomenon that we understand as music. In other words, it may be fair to state that a melody is music but it does not follow to assert that music is melody. That is to say that the poor perception of pitch and, in turn melody, by some CI systems/CIUs does not necessarily mean that music in general will be perceived poorly.

Realising that music recognition is problematic based on pitch cues alone, Vongpaisal et al. (2004) deal with the cues by which we are able to recognise and appreciate particular pieces of music. Various versions of familiar hit songs, performed with and without lyrics, were presented to prelingually deafened paediatric CIUs (8-18 years old). As with most studies of this nature, the performance of the CIUs was compared to that of a control group of NH participants. Subjects were played four versions of a piece of music: (1) the original commercial recording of a hit song that was judged as familiar by the participant (2) an almost identical version of the song minus the vocal mix (3) a synthesised piano rendition of the main melody and (4) a synthesised mix that outlined the bass parts and drum patterns of the original recording.

In a direct comparison between CIUs and NH subjects, the CIUs although marginally less accurate than the normal hearers, were able to recognise the songs with and without words. In general, however, piano and drum/bass renditions were identified successfully by normal hearers but not by CIUs. Despite the apparent processing problems of the CI systems, CIUs gave positive evaluations of the music that was presented to them.

### 1.5.3 Timbral and Instrumental Perception and Discrimination of Cochlear Implants

One simple way to define timbre is the property by which one sound can be distinguished from other sounds that share the same pitch and volume (Campbell & Greated, 1987). In musical terms, however, this acoustic definition may be considered slightly restrictive as the term timbre is often used as an indicator of the instrument's sound. Timbre perception, in this case, may be considered as the first stage of tone source recognition or in musical terms, the identification of the instrument (Roederer, 1973). Therefore, timbre can be seen to be a psychoacoustic device that allows us to differentiate between musical instruments based on both the spectra and envelope of the acoustic signal (Donnelly & Limb, 2008). Timbre, particularly the onset characteristics, is encoded via the temporal envelope and by the spectral shape of sound. In CI processing, temporal envelopes are usually well preserved, however, spectral information is inferior to that of normal-hearing listeners meaning that timbre recognition in CIUs is better than chance but not as accurate as in NH listeners.

The fact that CIUs perceive these relatively subtle acoustic cues through a processor designed to deal with language may mean that timbre perception is limited. As a result, the discrimination and identification of musical instruments based on their sound alone, can be a very challenging and confusing task for CIUs. This has been demonstrated in a number of studies (Gfeller and Lansing, 1991; Leal, Shin, et al., 2003, for example) that have explored the timbre perception, identification and discrimination abilities of CIUs. As with the majority of studies on other structural elements of music, the performance of CIU subjects are usually compared to that of NH participants when studying timbre perception. Gfeller et al. (1998 & 2002) report that CIUs generally display greater difficulty in instrument discrimination tasks than NH subjects and note that although NH subjects occasionally misidentify an instrument, they usually mistake it for another instrument of the same family. Implant users, however, may often misidentify instruments in a way that does not bare any relation to the instrumental family of the instruments(s) used as stimuli. Interestingly, in connection to some of the issues noted in the account of the pitch perception of CIUs (above) Gfeller et al. (2002) also note that the timbre perception of CIUs was far less accurate when stimuli was played in the higher registers of musical instruments.

The acoustic features of a signal that occur when a musical instrument is first played are crucial to the process of timbre perception (Campbell & Greated, 1987). Again, returning to the musical discourse, this means that the attack of the signal is one important feature in the discrimination and identification of an instrument based on timbre. This may provide something of an explanation for findings (Gfeller et al., 1998; Gfeller et al., 2002; McDermott et al., 2004) that CIUs display greater accuracy in the identification of percussion instruments (including the piano) when compared to other families of instruments such as woodwind or brass. The idiosyncratic nature of the attack of signals produced by percussion instruments, coupled with the distinctive way in which the are usually used in music, may actually provide a valuable temporal cue for CIUs thus assisting the identification of these instruments based on timbre.

In addition, participants in a study conducted by McDermott et al. (2004), were asked to rate the quality of the stimuli presented to them. Higher quality ratings tended to be assigned to the sounds that were most frequently identified correctly, implying that unsuccessful identification may be due to the poor representation of certain sounds and signals by the CI processing system. This study also dealt with the identification of other complex sounds in addition to music and showed that the ability of CIUs to identify both musical (solo singers/instruments and instrumental/vocal groups) and unmusical sounds (restaurant noise, for example) was relatively poor, an approximate success rate of 50%. Stimuli that presented recordings of single speakers, however, were quite successfully recognised, a finding which supports claims that the perception of simple speech by CI users is far superior to the perception of musical sounds. Interestingly, the sound of drums, although essentially musical in nature were generally recognised successfully. This serves as evidence to support the idea that examples of rhythm and the frequencies of non-tonal percussive instruments are generally perceived well by the sound processing technology used in cochlear implants.

## 1.6 Personal Variables Affecting Post-Implantation Music Perception

### 1.6.1 Practice and Training

Anecdotal evidence from CIUs suggests that there is a correlation between the extent of music exposure prior to implantation and their post-implantation music perception abilities. Despite significant variability in the general performance of CIUs it is the case that many people are able to achieve high levels of accuracy in open-set speech recognition tests following a period of use and experience with the CI in everyday listening and communicating situations (Gfeller et al., 2000). It has been suggested, however, that this is not the case with regard to music as the perceptual accuracy and enjoyment of music has no strong correlation with the duration of implant use (ibid.). This may be a result of CIUs being discouraged from music listening as a result of poor music listening experiences of the type often reported by CIUs in the period immediately after their 'switch-on'. Such poor experiences may deter them from future attempts to listen to music meaning that they may inadvertently exclude themselves from potential opportunities for music listening 'practice'. Despite claims that the duration of implant use does not correlate strongly with successful CI-mediated music listening, a number of studies have produced results suggesting that programs of structured training can improve the post-implantation music perception of CIUs.

A study by Galvin et al. (2007) probed the effects of training CIUs, coupled with personal practice, on a task involving the identification of pitch contours. Training occurred for a range of time periods (from one week to two months) and personal daily practice varied amongst participants from 30-180 minutes. Following the training/practice periods, each subject showed improved ability to recognize the interval of a minor second (one semitone), an improvement that increased as the training period continued.

The longevity of this improvement was tested in two participants two months after the cessation of the training period. Although a slight decrease in ability on pitch contour discrimination (when compared to scores immediately after the training period) was noted by the authors, performance was still significantly improved when compared to pre-training scores.

Gfeller et al. (2002a) observed the effects of training in a study of timbre recognition in 12 CIUs. All CIU participants were engaged in the training period for 12 weeks while the control group received no training. Results show that the experimental group (those who received training) performed significantly better than the control group.

The results of these and similar studies continue to demonstrate the important and beneficial effects of long-term training on cochlear implant-mediated perception of music.

## 1.7 Musical Experience

Having presented a review of the current literature in the field of 'CIs and music' it is clear that the main focus of the vast majority of this research is on the perceptual abilities of CIUs. This type of research is extremely important and contributes significantly to the understanding of the music perception abilities of CIUs and the processing abilities of the actual CI system and may aid the future development of implant systems or specialised music processing strategies, for example. The research outlined in this thesis takes a different approach to the majority of that which is outlined above by focussing on the musical *experiences* of CIUs; something which I believe to be a separate, albeit related, approach to understanding the area of cochlear implants and music. I believe that the perceptual ability of CIUs is only a contributing element to the general musical experience. However, as we will consider later in this discussion, auditory perception seems to have a central position in many of the ways in which musical experience is described or defined. Therefore, I will consider a number of issues that impact on our conception of the term with regard to the the role of perception and cognition, for example.

Music is something that is primarily conceived of in auditory terms. It is often encountered, disseminated, consumed and scrutinised by means of audio recordings, by performances in which people play musical instruments or sing, for example, thus producing a sonic stimulus (amongst others such as visual) which is primarily apprehended by the auditory system. In the case of printed music, although often used for analytical purposes, we can consider this as instructions (admittedly, culture-specific) to a suitably qualified person for how to interact with a musical instrument in order to create the aforementioned sonic stimulus, which may (or may not) be regarded as music.

It is obvious then, that there is a chain of events that begins with the emission of a stimulus and results in a person hearing sound (perhaps describable as music  see below). This chain can be considered in the following way: (i) the music signal is transmitted through the air (ii) upon exciting the auditory system it is transuded into an electrical signal (iii) this signal becomes a nervous impulse which ultimately has a psychological response in the form of sensation. In the case of music, such sensations include pitch, timbre and volume, for example. Therefore, in general terms, we can see that an external stimulus has excited a sensory organ significantly enough to generate sensation. With regard to sound, in the case of CIUs, however, this sensory organ can be considered as being bypassed due to the nature of the implanted auditory system (see above). Regardless of the details of the auditory system, the CI system's stimulation provides the CIU with the opportunity for sensation and consequently perception.

Perception then, can be conceived of as the stage at which we interpret our sensations by way of developing comprehension of the external world. Hypothetically speaking, it would be at this stage that (when presented with sensations relating to pitch, volume and timbre, for example) we would become aware that the stimulus we are being exposed to is, for instance, a loud C# played by a flute. Put simply, it is at this stage where we make sense of our sensations as representations of the real world cause of sensory input (Gleitman, 1996).

There are numerous internal processes that relate to the way we hear, listen to, react to and understand music that have a bearing on this discussion, many of which relate to the interdisciplinary area of music cognition, a field which strives to comprehend the various mental processes that enable interactions with music from the perspectives of perception, comprehension, memory, attention and emotion, for example. That is to say that the field of music cognition focuses primarily on how the mind makes sense of music as it is heard but deals with the way in which this relates to and informs other areas of musical behaviour, such as performance, composition, communication and interaction. The purpose of the current discussion is to outline a framework for the comprehension of musical experience within this thesis. Therefore, a brief outline of what is meant by music cognition and the way in which it may contribute to musical experience is sufficient for the current discussion and the contextualisation of those that follow, throughout the thesis.

Dowling and Harwood, (1986), state that they view the music listener as a '. . . gatherer and interpreter of information from the environment . . . ' (ix) something which, also betrays a bias towards sensory perception, at a basic level but one which acknowledges the role of the 'perceiver'. From the perspective of music cognition it seems then that there is also an importance placed on sensation and the perceptual mediation of such. However, the attention to sensory perception is situated within the context of the interpretation of sounds as musical events, something that is also highlighted by Dowling and Harwood:

> 'Our sensory systems receive information about the world. Sensations are filtered through perceptual processes that direct attention to important events. But even important signals  those that might deserve our attention  are often too numerous to handle. . . . Musical sounds and the musical actions of others are environmental stimuli that are important. . . sensed by our ears and eyes and interpreted in the context of our memories.'. (ibid., p4)

Therefore, the cognitive experience of music is something that relies not only on the perception of a stimulus but something that depends on the interpretation of sensory input with regard to other internal factors such as prior experience, memory, expectation, for example.

Serafine (1988) talks not of 'music cognition' but of 'music *as* cognition' by way of stating that she believes that music does not exist as some external manifestation such as a recording or score or even in the perception and sensation of sounds, but rather in the form of cognitive constructs. This is to say that the idea of music *as* cognition, rather than the cognition of music, for example, means that music's very existence is in a mental world of thoughts and knowledge relating to sounds and the relationships between them and a person. Similar arguments are outlined below but it is particularly interesting to mention the idea of music as cognition in order to present a subject-centered approach to this area.

Another approach to the study of music cognition is w by the area of embodied music cognition, which is concerned with studying the role of the human body, and its actions in relation to musical activities. This approach views the human body as the mediator between the mind, the physical environment and musical signals at the physical level (Leman, 2007) and, therefore, views music perception as being based on action. The view of embodied music cognition is that corporeal movements are interpreted as an active personal involvement of a subject listening to music (De Bruyn, Leman, & D., 2008), which relates to perceived structural elements of the music and to the experience of emotions in response to music. Therefore, embodied and enactive cognition studies emphasize the inter-related roles of environment and the body in shaping mental process and experience (Varela, Thompson, & Rosch, 1991).

Gody and Leman (2010) believe that experiences of music are intimately linked with experiences of movements. They state that as music is essentially a combination of sound and movement (i.e. musicians create music with movements, and people make, or imagine, movements when listening), that music has meaning as a result of this combination. Therefore, this type of meaning-formation is said to be embodied as it is understood and experienced through the human body. This is in contrast to more traditional approaches to music cognition, which typically understand musical meaning and experience to be based on the perception, analysis and interpretation of structural elements of the music. Embodied music cognition is, therefore, based on the consideration of both perception and action and the relationship that exists between such areas.

As is alluded to above, when considering the nature of musical experience it is extremely important to consider the both the nature of music and the way in which it is experienced. I believe that in order to gain an idea of what is meant by the term musical experience, it is important to be aware that this relates to philosophical issues surrounding the nature of music and the experience of such in addition to the way in which musical experiences are formed, understood and evaluated. Discussing the nature of musical experience and the way in which it has been considered philosophically, brings into question the term 'music' and what it means and refers to. Therefore, I will outline relevant ideas in two separate categories, namely; object-centred considerations and, subject-centred considerations. For the purposes of this thesis, an object-centred approach to the study of musical experience will be considered as one that views music (in whatever manifestation) as the central component of the experience, i.e. the musical object is that which is to be experienced.

Igor Stravinsky in his 'Poetics of Music' (1947) discusses 'the phenomenon of music' and approaches this discussion chiefly from his perspective as a composer. Stravinsky suggests that the phenomenon of music (musical experience) is available only to those who possess the 'full resources of their aural senses, psychological faculties and intellect' (ibid.). This is particularly interesting in the context of the current research as we have a situation in which a composer, i.e. someone who is creating music (in some sense), specifically linking musical experience with the aural senses and the efficacy of such. This coupled with his inclusion of the requirement for psychological faculties such as intellect gives the distinct impression that music (and the experience of such) is viewed as something that exists as an ideal or perfect entity, which must be perceived and considered intellectually.

The idea that the musical experience is an objective experience (i.e. an experience of the object) is one that favours attention to the perceivable qualities of a work. Monroe C. Beardsley, writing about the evaluation of artworks, (1958) proposes that one should firstly, observe the parts that form the work and, secondly, consider how these parts contribute to the nature of the whole. It is suggested that a musical composition is a complex event that consists of smaller events that can be described as small changes '…from something to something…' (ibid., p.97); high-pitch to low-pitch, loud to quiet, for example. Beardsley suggests that the 'termini' of such musical changes are sounds and that these sounds should be regarded as the elements of music. It is the evaluation of such elements that constitutes acceptable criticism from which any aesthetic experience is derived. Again, as with Stravinsky's claim above, this way of thinking about musical experience and, in turn, the nature of music generally, places a strong emphasis on (a) the ability to perceive sounds and, (b) the ability to consider them individually and as contributors to a greater framework. This type of object-centred approach to the nature of musical experience highlights important issues relating to what is understood by the term 'music' and how it relates to experience.

This gives rise to three important issues relevant to the understanding of musical experience generally and within the context of this thesis. Firstly, in an object-centred approach to musical experience it is clear that music is considered as an external object, which is to be perceived in order to have a musical experience. It follows then, that an implication of such a perspective is that any diminished capacity for perception or the ability to apprehend the formal or structural elements of the music would ultimately lead to a lesser experience or, potentially even prevent such experience. In this sense, musical experience can be considered to be the experience of the structural components of music and the intellectual process of evaluating the individual and combined nature of such elements within a musical context.

Secondly, such an object-centred approach to musical experience tends towards the aestheticisation of musical objects, i.e. the consideration of idealised artistic forms. In this sense, notions of aesthetic experience and musical experience become somewhat synonymous. This is further emphasised by Harry S. Broudy, who suggests that the aesthetic experience results primarily from sensory perception in that any aesthetic object '…will always be an image or a cluster of images.' (Wright, p.37; in Reimer  Wright, 1992). This aesthetic image will, of course, differ significantly depending on the mode in which the art form is expressed, but it will deal entirely with imagery rather than fact or even theory, for example. In this sense, the aesthetic experience is primarily perceptual in that it requires the recognition of those sensory properties that are essential to the experience of the object. Aesthetic experience results from the formal properties of the aesthetic object with regard to its design or composition, which are the result of conscious choices by the artist. It follows then, to suggest that any change to such properties will have an aesthetic impact on the object itself.

How then, does the concept of aesthetic experience inform our understanding of musical experience? In some cases outlined above (which provide only a general and in no way exhaustive assessment of theories) it seems that 'aesthetic experience' with regard to music, and 'musical experience' may be synonymous; however, I suggest that such conceptions of aesthetic experience are inadequate as accounts of musical experience as they neglect to comment on the effects of the music, or the situations in which the music is experienced. If music is to be regarded as an external stimulus to be perceived and scrutinised and the aesthetic experience is derived from such processes then it would seem that there is a presumed gulf between that which is to be perceived and the perceiver, something that I believe to be problematic (see below).

Thirdly, the view that music is an external object to be perceived by those who have the full function of their aural senses and intellect, for example, suggests that only some kind of ideal listener who fits such criteria can experience the phenomenon of music. In David Hume's essay 'Of the Standard of Taste' (1757) he states that the standard of beauty is the common verdict of supremely qualified critics. Hume provides a number of criteria that constitute such critics: '. . . Strong sense, united to delicate sentiment, improved by practice, perfected by comparison, and cleared of all prejudice' (ibid.). Although Hume states that '. . . the joint verdict of such, wherever they are to be found, is the true standard of taste and beauty.' (ibid.), he is essentially implying that those who do not meet this category are unable to engage with the formal characteristics of the object at an appropriate level and therefore garner a lesser aesthetic experience; i.e. the conditions of the subjective experience need to be excellent order for a person to be functioning with 'excellent taste'. Put simply, although for Hume the aesthetic experience is subjective, it seems that he conceives of a type of 'ideal' or expert listener who is ideally capable of assessing an aesthetic object.

As can be seen from the discussion above, an object-centred view of musical experience is largely connected with the apprehension of the perceivable qualities or elements of the music which accounts for it's connection with the notion of aesthetic experience. I believe, and propose for the purposes of this thesis, that the concept of musical experience should be considered as far wider than (but potentially encompassing) that of aesthetic experience  not, in any way, dependant on it. That is to say that aesthetic experience (or one's aesthetic judgement), i.e. that which is strongly linked to sensory perception, may inform or be considered as a part of musical experience but not the entire experience due to the influences and impact of music which are far more numerous than only those considerations of it's perceivable qualities.

A subject-centred approach to the concept of musical experience, however, is one that focuses on the experience of the music rather than its construction or perceivable elements. In this sense a person's musical experience can be derived from a multitude of sources (natural or otherwise), providing they interpret the essence of the perceived sound to be musical, in some respect. This is in contrast to the object-centred approach which views the musical object as having inherent musical/artistic qualities which are to be perceived by a suitably qualified subject.

Thomas Clifton, taking a phenomenological approach to the concept of musical experience, suggests that we cannot think of music as an entity that exists in the world in the way that mountains and buildings do, for example, but as a humanly meaningful way of being that exists between sound and the human (Bowman, 1998, 268). This is to suggest that without the presence and involvement of a person, there can be no music (ibid.). This phenomenological view provides a perceiver-oriented, humanistic approach to the concept of musical experience, which sees music as intrinsically linked to human experience, and thus does not conceive of the dichotomy of 'that which is known' and 'the knower'. Music is for Clifton, therefore, the product of a relationship involving a person and sounds (real or imagined); it is a reciprocal collaboration in which neither party is superfluous or dispensable.

Although sounds are undeniably the materials that bear music, sound is not music and music is not reducible to sounds, simply that '. . . the musically behaving person experiences music by means of, or through, the sounds.' (ibid.). However, Clifton considers the concept of objective' aesthetic standards to be pedantic and patronising in that he feels that he has no right to demand or assume that any other 'musicing' [4] (ibid.) person should experience a piece of music in the way same way as he does. Music, in this case, is not considered an object separate from the perceiver, but an experience dependant on the perceiver. Thinking in this way allows us to conceive of music not as something external to be perceived and considered from a distance but rather, as something that directly involves the perceiver in some way. Therefore, Clifton's definition of musical experience involves the listener in the question of whether or not a sound stimulus is music and says nothing about the standards that the object is supposed to meet, or indeed the qualities of the 'excellent perceiver' as in Hume's conception of aesthetic experience. We can, therefore, imagine a situation in which sounds that are not intentionally musical can be considered as such, or even as music, because of the collaboration between them and a person or group of people. Machinery-sounds, for example, could be considered musical in the presence of a complicit person who experiences something musical (rhythmic pulse, for instance) as a result of being exposed to such sound.

Clifton also relates his definition of musical experience to aspects of music theory such as; pitch, interval, harmony and tonality. Regarding pitch (for example), it is suggested that we experience music through pitch rather than experiencing the pitch itself  we hear the musical activity of the pitch (the concept of pitch is discussed above). In the example of machinery-sounds, above, it could be said that we experience music through the machinery-sounds, it is not the music itself since

[4] 'musicing' is also spelled 'musicking' by some authors such as Small (1998).

the music only exists in the combination of the sound stimulus and the experience of the human perceiver. He does not deny that sounds, the techniques required to produce them or any notation which may represent them are all vastly important aspects of music, but states that they are *not the music itself*; a view that is in contrast to those of the empiricist thinkers who regard musical experience as primarily (if not exclusively) sensory. Clifton does not dispute the importance of sensory perception in the musical experience but suggests that there is no music without a 'musicing' person, again highlighting the importance of considering music as an experience that directly involves and is equally dependent on the perceiver. This is further emphasised in reference to 'feeling' as it is suggested that feeling, like space and time, is a necessary constituent of the musical experience rather than a psychological bi-product of the listener.

The view that music does not exist, per se, as an entity or external object and that it exists only in a people/sound nexus is one that is echoed, to some extent by Christopher Small. It is suggested that music is not a thing, or an object at all but an '...activity, something that people do' (1998, p.2). As a result we can conceive of music (the apparent thing or object) as an abstraction of the process of engaging with music hence 'musicking'. Small makes the parallel between such abstractions as love and evil, which (in common with the idea of music) do not exist out with the abstraction of the action of a loving or evildoing person, for example. It is asserted that coming to think of the abstraction as more real, in some way, than the action is a danger of reification, which potentially leads to the objectification of the abstraction. This is problematic in the case of music as it can lead to the abstraction being considered as something real or concrete. If music is considered as something real or as an independently existing entity then I believe that this leads to object-centred considerations of musical experience which, as discussed above, typically place a great deal of importance on the sensory perception of the object's formal or structural qualities.

Although Clifton and Small's theories differ slightly with regard to the actual idea of music and its mode of existence, they are both particularly interesting in the context of this thesis due to their acknowledgement that music necessitates a musicking person. That is to say that the idea of music (and the experience of such) relies on a complicit person who is actively engaging in/with music, i.e. the range of actions or activities implied by the abstraction music'. Musical experience is, in this case, something that is derived from the process of musicking and relies equally on sound and a person since music, and the ability to experience it can only exist as a product of this relationship. The subject-centred approach acknowledges (and embraces) that the musical experience is shaped by the subject's prior experience and knowledge, for example, and does not presume to state that the experience of music should be universal or that music even exists in the form of an idealised external object with perceivable qualities.

For the purposes of this thesis, I believe that a subject-centred concept of musical experience is a sound philosophical starting point as: (a) it does not treat music as an external force, the form and structure of which to be perceived, evaluated and appreciated; (b) Nor does it imply that the object is the perfect representation of creative output of an artist - with universal criteria by which it's 'beauty' (or the 'taste' of it's perceiver) should be judged; and, (c) it allows us to conceive of the musical experience as a reciprocal relationship between stimulus and perceiver in which the concept of music's existence is inextricably bound. The relationship between the person and the sound is imperative for musical experience and is individual, i.e. it should not be assumed that one's experience of a piece of music is necessarily the same as someone else's even if the stimuli are identical (at the point of emission, at least). Nor does it assume that any one person is more qualified (physically or mentally) to have a musical experience and thus does not entertain the concept of ideal' listening or listeners or make value-judgements about the experiences of others.

When considering the musical experiences of CIUs, coupled with our awareness of their potential difficulties in the accurate perception of musical stimuli for this group, we can see why it may be possible for positive musical experiences to occur despite impoverished sonic stimuli (something for which evidence is presented in subsequent chapters). I believe musical experience to be perceiver-oriented and not exclusively dependent on one's potential for perceptual accuracy, aesthetic experience/judgement or even the need to believe that experience of particular music is universal and irrespective of individual differences at a personal level. Additionally, if we accept that the musical experience is perceiver-oriented then it is reasonable to suggest that there may be a number of other relevant factors that contribute to this based on the experience of music within a wider social context, for example.

In many cultures and societies, music is an almost ubiquitous phenomenon that permeates many areas of people's social and cultural lives. As is stated by Overy & Molnar-Szakacs (2009) 'Music is clearly not just a passive, auditory stimulus, it is an engaging multisensory, social *activity*'. Music is at the centre of many aspects of our social lives such as concerts where people meet to listen to and scrutinise the music; or performances/jam-sessions where people congregate to engage in musical performance and interaction on a musical level with each other. It is also an important, if not central, contributor to a great number of the ceremonies that mark significant moments or events in people's lives (Crozier; in Hargreaves  North, p67) in both secular and religious situations. The position that music has within such areas of society leads to a situation where it becomes something more than an external auditory stimulus; it becomes a central component of the situation. In some events and ceremonies music is a significant element that may become strongly associated with the event, for example, the first dance at a wedding, or the music for a funeral. It is obvious in such examples that the experience of the social situation (i.e. the wedding) can be greatly influenced by the presence of certain music but it may also be stated that the musical experience is largely influenced by the social situation, both immediately and upon subsequent hearing of the music. In this sense, we may also be able to consider the enduring effects of this experience with regard to associations that may be rendered due to the circumstances in which it took place.

Consider the example of someone hearing (perhaps many years later) the song that accompanied the first dance at his or her wedding or music that was played at the funeral of a loved-one. Hearing this music subsequently (in inevitably different circumstances) may invoke similar emotions or memories of the social event. DeNora (2000) suggests that for many people, '...the past comes alive' to its soundtrack' (p.67) as a result of the fact that music associated with a particular time and place can serve as a tool with which it is possible to replay, and become reminded of the time and place it was experienced. This is not simply in the sense that memories of past experience may remind someone of music that may have been present at the time; rather, that any music would have been experienced temporally and that such music, when remembered or heard subsequently, allows for the mental exploration of the 'temporal structure of that moment'. Similar connections can be said to exist between musical experience and interpersonal relationships.

For CIUs, such a relationship between music and social experience also depends, to a large extent, on their individual history of deafness. The relationship between musical experience and history of deafness will be explored more in chapter 3, however, for the purposes of the current discussion, it is sufficient to draw attention to the possibility that the musical experiences of congenitally deaf CIUs may be very different to those who were deafened later in life, for example, due to the contrast in previous experiences and interactions with music on a normal-hearing basis.

Another function of music in the social context I wish to draw attention to in this chapter relates to the types of music that an individual chooses to associate themselves with in the sense that it can serve as a tool with which a listener can construct or manipulate an environment designed to reinforce and project their personal values or perceived self-image. DeNora (ibid., p.47) suggests that research in this area relates to the way in which music is '. . . appropriated by individuals as a resource for the ongoing constitution of themselves and their social psychological, physiological and emotional states'. Therefore, there is a focus on the way in which an individual can use music and socio-cultural practices in order to shape mood, memory and identity'. Music's social functions, for both musicians non-musicians alike, can be manifested in three main ways, namely; 'self-identity, interpersonal relationships and mood' (Hargreaves  North, 1999:p78). Although it is proposed that musicians and composers, for example, can use their music as a way of expressing and defining their identity the focus in this chapter is on the consumptive rather than productive consideration of musical experience.

Music can be a powerful agent in the process of people's self-definition and place within groups such that the type of music people choose to listen to can be a way in which they are able to define themselves and investigate their personality and self-views. Music, or perhaps more accurately, musicking, can serve as a device which people use to regulate themselves as aesthetic agents (DeNora, p.62) in their day to day lives. DeNora suggests that this regulation requires a high degree of reflexivity that is apparent in the form of the demands of social circumstances, which cause the 'need' for such self-regulation, and in music's role as a contributing factor to self-identity. Engaging with music can be seen, in some cases, as a presentation or projection of oneself to others but also as a presentation of self to oneself such that it allows for us to construct an image of whom we see our selves (and wish for others to see us) as. It is in this way that music can serve as a tool for the reflexive process of constructing an identity, remembering this image of self, and as a tool for the creation of future identity (ibid.).

Zillmann  Gan (in Hargreaves  North:1997) suggest simply and succinctly that '. . . the exhibition of one's musical taste is used to distinguish oneself' (p.173). This is also stated by Frith (1981) who claims that, in general terms, adolescents use music as a 'badge of distinction'. Again, using music as a way to create a self-image and associate (or distinguish) oneself with/from social groups is a legitimate and common function of music but does not necessarily rely on the successful perception of the musical elements. This is apparent in the form of conformity effects in musical preference, for example, where choices and evaluation often reflect a desire for acceptance into social groups (Hargreaves North, ibid.), which are often closely linked to the musical and in turn, cultural values of its members, not their ability to perceive and assess the structural components of music. In fact, the actual sonic components of the music are secondary to the subscription to the ideas, values, fashions or social groups associated with it. This is to say that in some cases, with regard to this use of music, the musical experience and its wider implications do not rely on the successful perception of the musical elements of the musical object.

Although people use music in a multitude of different ways, Frith (1987) suggests that there are four main functions of (popular) music in particular: (a) to create a form of self-definition, (b) to create a way to manage and balance private and public emotional life, (c) to shape and construct popular memory thus organising one's private sense of time and (d) to provide a feeling of ownership or possession in a musical sense. The notion that music could be, in part, responsible for such important factors of someone's life as the definition and projection of their perceived self, the understanding and creation of their own position in society and the way in which they are able to display and deal with emotion, suggests that music is related in no small way to social identity and therefore impact greatly on the musical experience. However, I do not believe that these functions of music rely on the accurate perception of the formal or structural elements of the musical object.

Musical tastes, preferences and the values that are inevitably placed on such feelings, contribute greatly to an individual's potential acceptance in or 'membership' of a particular social group. As it is the case that so much importance, in a social context, is placed on one's musical tastes and values it is understandable that the musical experiences of CIUs, and evaluation of such experience, can be based on factors which do not necessarily relate to the efficacy of perception or the actual sound of the implant-mediated music signal. I believe that when considering the musical experiences of CIUs it is important to realise that music choices, musical preference and the general musical experience are the result of a great deal more than the simple evaluation of perceivable qualities of the apparent musical object.

Musical experience is clearly a wide-ranging concept and I believe that the most appropriate way to deal with the issue is to reflect on the way that it will be considered in the context of this thesis but to acknowledge the fact that a global definition of musical experience is one that, if at all possible/appropriate, is not the concern of this work. Given the multitude of conceptions of what might constitute musical experience and the huge variety of personal variability that characterises the people who are the focus of the current research, it may be most appropriate to consider musical experience by way of generalised factors that contribute to and inform it.

Musical experience is a coalescence of a multitude of factors that relate (in general terms) to: (a) perception of the stimulus, (b) one's personal comprehension of the 'music' with regard to both the current situation and previously acquired associated knowledge, and, (c) one's general comprehension and awareness of the place of music and that of the musicking person within a social, interpersonal and environmental context. Therefore, I propose to consider musical experience, *for the purposes of this thesis*, as an amalgamation of many factors that can be represented generally by way of the following framework:

It must be made explicitly clear that I propose that musical experience, for the purposes of this thesis, should be considered as a phenomenon that potentially encompasses influence from each of the categories (which are, themselves, interrelated). Also, within this framework, a positive musical experience does not necessitate a positive experience in each of the categories noted above, as exemplified by the following hypothetical scenario.

Consider a CIU who reports that their perception of the musical elements of a piece of music is very poor and that consequently, they felt that they were not able to have a positive experience of the perceptual auditory elements of the music while listening to it (point A). However, it may have been the case that enjoying

| Category | Relevance | Description |
|---|---|---|
| Sensory Experience | Perceptual awareness/experience | The awareness of sensory input with relation to the formal/structural elements of stimuli. |
| Cognitive Experience | Internal awareness/experience | The interpretation of sounds as musical events, based on cognitive factors such as expectation, association or emotional connections, for example. |
| Social/environmental experience | External awareness/experience | Social and cultural factors, the experience of music within such contexts and physical environments. |

Table 1.3: Proposed Framework for the consideration of Musical Experience Within This Thesis

the spectacle of the performance provided a positive sensory experience with regard to vision, as opposed to audio, for example. This is something which I believe should not be dismissed simply because it does not relate directly to the sonic/structural elements of the music. The CIU may remember the music from before they became deaf and, although potentially unable to perceive it as they did before, may be able to relate it to their memory/mental representation (point B) of the music and thus feel involved in the experience. Also, they were at the concert in which this music was performed with a group of close friends and they enjoyed the company of their companions, the ritual of going to the concert and experiencing the non-sonic elements of the event (point C).

Although this is a hypothetical scenario, similar situations are frequently reported by CIUs, i.e. that positive musical experiences can be derived despite poor access to stimuli as a result of other factors; evidence for this is provided in subsequent chapters. Having presented a discussion of the nature of musical experience and presented a framework outlining the way it will be considered throughout this thesis, a number investigations into this area will be set forth in the following chapters in addition to some proposed strategies for improving the general musical experience of CIUs.

## 1.8 Conclusions

Studies which focus primarily on the music perception abilities of CIUs provide very useful information which is of great interest to many groups of people, including CI manufacturers, hearing rehabilitation professionals or audiologists, for example. The current research will approach the study of CIs and music from a different perspective by focussing on and aiming to improve the musical experiences of CIUs. Musical experience is not simply related to a person's ability to discriminate frequencies or identify rhythms, note changes in tempo and describe pitch contour, for example. Nor is it directly related to how accurately people can determine and identify the sound of a particular instrument. If so, in the worlds of contemporary pop music, electro acoustic composition, hip-hop and dance music, for example, which rely heavily on synthesised sound that either bares little resemblance to the sound of the instrument it is imitating or, that is used simply as a sound and is not intended to be representative of a 'traditional' instrument, most people would be deemed to be 'unsuccessful' music listeners. Of course, the 'mechanical' process of music listening relies on and encompasses elements of all the aforementioned abilities and many others but this is purely a perceptual/sensory concern and does not fully account for the complexity of musical experience.

In addition, based on the methods of most of the studies noted above, it seems to be a near-universal experimental practice to compare 'music listening' abilities of CIUs to that of normal hearing subjects. As a result, it is often concluded that CIUs have 'more difficulties' or that their (CIUs) performance, when listening to music, is somehow inferior to that of the NH control groups. Although a great deal of the information and data gained from the aforementioned studies is of great use to CI manufacturers, psychologists, hearing rehabilitation professionals and audiologists, for example, I believe that the 'real-world' musical experiences of CIUs are at risk of being misrepresented. This is a problem that I will address throughout this thesis in an effort to make an original and meaningful contribution to the existing knowledge relating to the 'real-world' musical experiences of CIUs.

Gfeller et al., (1997) suggest that measures that relate to a global view of music perception may not adequately consider the various listening tasks used and experienced in music listening. As a result, it is suggested that such global measures may fail to determine which of the various listening tasks are successfully or unsuccessfully accomplished using the CI system. The authors note that, conversely, studies and tests investigating specific and focused elements of music perception are unable to represent the true complexity of CI mediated music listening experience.

I propose, therefore, that 'music perception' and 'musical experience' (as described above) are two distinct subjects that should be considered separately. Considerations of music perception are based on the actual way in which the music is 'perceived' by the CI system and, in turn, the CIU. This subject area deals with the specific listening tasks involved in the process of music listening including pitch discrimination, timbre recognition and rhythmic identification and rarely, if ever, relates to the human subject who is perceiving such elements. Contemplation of musical experience differs from music perception as it is based on a holistic view of the way people experience music, its uses, meanings, social functions, and importance in people's lives, for example, in addition to the way in which the music is actually perceived.

Another distinction that may be drawn between the study of music perception and musical experiences is the role of the music. In studies relating to music perception, the music is considered as the stimuli used to provoke responses from the subjects in order to obtain data. It is designed solely to test specific areas of perception and is, as a result, viewed as a manipulation tool. The role of music in the study of musical experience is somewhat different in that it should be considered to be a subject of equal importance to the human subject it is being presented to. In addition, the study of music perception aims to generalise the way in which music is actually perceived. It looks to suggest or disprove theories towards the mechanisms and efficacy of music perception in general and does not often account for the effect on the individual. Conversely, the study of musical experience is primarily interested in the way that individuals experience, use and interact with music in everyday situations and embraces differences and subjectivism. Thus, although the process of perception is by its nature experiential, I suggest that considerations of perception and of experience are two distinct, yet related, issues based on the evidence presented above.

The rationale for the focus on musical experience in this research has also arisen due to conversations and other contact with many CIUs has further emphasised the fact that musical experience is something which may be related to music perception but is not solely dependent on and certainly not synonymous with it. This is highlighted in chapters 2) and 3 which outline, generally speaking, investigative contact with CIUs in the early stages of this research. The following chapter outlines moves away from discussing current literature and the studies of others to outline my ‘real-world’ experiences of working and interacting with CIUs during an internship at the Hearing Rehabilitation Foundation (HRF). This work included the organising and running of a music focus group for adult CIUs and a four-day music group/workshop for child CIUs and had a significant effect on the development of my interest in musical experiences. Important face-to-face contact with CIUs during this time greatly influenced my ideas and thinking and was invaluable in the early stages of this work.

# Chapter 2

# Investigative Music Groups for Adult and Paediatric CIUs

## 2.1 Introduction

This chapter is based on work that was conducted in Boston, Massachusetts with Geoff Plant in the early stages of this PhD research (June 2007). Plant is a teacher of the deaf and aural rehabilitation specialist of the Hearing Rehabilitation Foundation (HRF) and MED-EL (Now MED-EL UK). This work was undertaken as an internship at the HRF that was spent working on music-related activities for both adult and paediatric CIUs and can be divided into three main sections: (i) discussions with adult CIUs about their experiences of music from both a pre and post-implantation perspective; (ii) planning and running a music focus group for adult CIUs; (iii) planning and running a four-day music workshop for paediatric CIUs.

This chapter will fulfil the dual role of outlining my experiences of planning and running groups of this nature whilst also describing information that was discovered about the research area of CIs and music as well as insights gained through the CIUs with whom I had contact. Such insight has proven to be extremely useful in the formative stages of this research and influenced the way I have approached and considered many of the issues that relate to this research area. Based on knowledge of this field (see chapter 1) and observations of and conversations with a number of CIUs (and their family/friends, for example) it is obvious that a variety of issues relating to the implant-mediated perception of musical information lead to poor or diminished access to the acoustic signal of music. Despite this, however, many CIUs report *positive* appraisals of music, in some form, if not specifically the *sound* of the music. This issue was discussed in chapter 1 and it was noted that the focus of the current research will be on musical experience rather than music perception, per se, and it is important to note that this focus was was inspired and developed during the period in which the work described in the current chapter took place.

## 2.2 Music Groups for Adult CIUs

During the internship at the HRF, one of the main aims was the planning and conducting of a focus group for adult CIUs, primarily focused on the subject of music listening. When planning this it was necessary to consider a number of different factors, including: the specific purpose of conducting the session, the inclusion criteria for potential participants to be invited and, in turn, the activities that would be included in the session, based on the previous two considerations.

We believed that the participants would find group situations (rather than one-to-one sessions as is common for rehabilitation work) of this nature useful as many people enjoy the opportunity to participate in a group where other people are in the same or a similar position to themselves. This may be due to the fact that some participants feel reassured by the knowledge that other people are experiencing similar problems and difficulties; being in this position and talking with other participants may lead to them discovering ways to deal with or accept their own frustrations based on the experiences or solutions that others have found to similar problems. In addition, the fact that this type of advice may be offered by other CIUs who experience similar problems make them seem more valid than if put forward by therapists or teachers, for example.

Another potential benefit of running a group session is that the organisational, logistical and financial elements are greatly reduced since only one session is being organised, planned and paid for. Although it may seem strange to include financial considerations in work of this nature, it is a particularly pertinent point that affects charities and health services alike and must, therefore, be taken into account when planning this type of work. Plant conducts focus group sessions for the HRF and MED-EL UK with groups around the world and his format was used as a starting point for the development of the session described below.

The purpose of this focus group session was twofold - specifically; an opportunity to gain rich, real-world information about various aspects of music listening from the CIUs *and*, that the session should be enjoyable to the participants so that the process was an exploratory, enjoyable and informative experience for both the participants and for us (Plant and I) as the organisers/facilitators, in the role of participant observers.

### 2.2.1 Participants

'Experienced' CIUs can be described as people who have obtained a stable understanding of speech and who are able to communicate aurally in a normal conversational setting. As the session was intended to be an exploratory and informative experience it was decided that only CIUs who could be described as 'experienced', as per the definition above, with some pre-implantation memory of music would be invited.[1] During the planning process Plant noted that, having discussed this with a number of clinicians and therapists, that this level of experience is unlikely to be attained until at least six months after the implant is activated. During this six-month (approximately) period CIUs may still be adjusting to the sound of speech and other ambient sounds; thus spending time focusing specifically on music during this time could potentially lead to confusion and may make the process of adjusting to the implant more difficult or prolonged. CIUs taking part in focussed music listening sessions during this time adjusting period might also give skewed representations of their music listening experiences based on the current stage in their rehabilitation process.

Additionally, the decision to invite 'experienced' participants of this nature was taken so that everyone in the group would have a similar level of competency with the implant (at least for speech) in order to minimise the risk of anyone feeling insecure based on their communication ability or general experience of implant use. In addition we wanted the group to have a memory of their pre-implantation experiences of music as this would allow us to gain an idea about the way their experiences of music had changed since receiving their implant, thus providing more useful information.

[1]The term experienced may have varying definitions for different people but this was used as a working definition for the purposes of recruiting participants for this focus group session

Having stated that our criteria for inviting participants was based partly on their ability to communicate aurally in a conversational setting, the size of the group was also a consideration. Given the nature of their condition, and the fact that the session would involve a great deal of focused listening, too many participants could have lead to an increased level of noise and conversation which can, in a large group, lead to communication problems amongst participants. This could result in people feeling insecure or nervous which had the potential to stifle conversation amongst the group. Another decision taken to make participants feel at ease and comfortable in the group was to allow a member of their family or a friend to attend the session, if space permitted. Although, as noted above, we were conscious that we wanted to limit the number of participants it was felt that allowing family members or friends to attend could encourage attendance and make participants feel more secure thus, in turn, encouraging them come to the group and to participate in discussion and activities. A secondary benefit was that it afforded the friends and families of the CIU participants to communicate with each other and, as with the CIU participants, offer support and guidance relating to the way that *they* deal with, help and support the implanted person with whom they have attended the group.

### 2.2.2 Participant-led Discussion

When planning the session, our primary concern was to plan activities that would be inclusive, encouraging and that would not be conceived of as ‘tests’ (in the sense that the participants could, depending on their contributions, pass or fail), but simply as starting points for discussion. The activities were designed to provoke and stimulate discussion and comment from the participants in the hope that they would provide us with useful information relating to their musical experience and how this has changed since receiving their implant.

We thus began with an open group discussion about musical experiences, giving each of the participants a chance to comment on their own personal experiences. This discussion was chaired by Plant in order to make sure that discussion did not become irrelevant and to stimulate the discussion in the case of reticence in the participants. Also a brief period of time was afforded to the friends/families members to talk about their observations on the way in which the cochlear implant has affected the CIU participant.

In any group session where the members of the group are unfamiliar with each other it is understandable (perhaps inevitable) that some participants can feel uncomfortable or insecure about speaking in front of the rest of the group. This is something that can lead to less open or honest discussion or hinder the process of gaining information on the topic of the focus group; in a group of CIUs particularly, this problem could be more prominent due to the potential communication and confidence issues sometimes associated with CIUs. Therefore, strategies for encouraging and stimulating discussion amongst the group were considered.

By way of beginning this discussion, Plant (in the role of chairperson) asked each of the individual participants to share details of their musical experiences, focusing specifically on any differences that they noticed between their pre and post-implantation experiences. An open question of this nature was used as it could be approached in many different ways by the participants and therefore has the potential to provide some interesting responses. In addition, such a question had no *'right'* or *'wrong'* answer so participants were more likely to respond honestly and openly without consideration for whether or not their answer would be the correct one or 'the one we were looking for…', for example.

It was presumed to be sensible, when prompting the individual participants to share their experiences, to try to begin with the more confident members in the group. As the participants gathered in this situation were all known to Plant, this meant that we had prior knowledge of their personalities and conversation abilities. We started the conversation in this way so that the less confident members of the group were encouraged to speak and reassured that the group is an open and supportive environment.[2]

### 2.2.3 Music Activities

Again, when planning the music activities for the group we were conscious of the fact that the session should be engaging and fun for the participants and that they should not feel pressured by the activities. Therefore, it was decided that we would

[2]Participants who were reluctant to contribute to the discussion were not forced to participate or made to feel any less comfortable but were asked more specific questions, relating to their musical taste, their favourite artists or even their least-favourite artists in an attempt to find something more directly related to them that they might feel more passionate about or interested in sharing their opinions on.

present a range of activities that would include simple music questions, live performance evaluation and recorded performance evaluation of audio and audiovisual materials. In doing this we believed that we would be able to gain useful first-hand information from the participants relating to the way that they experienced various methods of music presentation and also to observe their abilities to recognise melodies and to distinguish between different melodic phrases.

**(i) Music-Listening Questions:**

Our objective in setting music-listening questions for the participants was to gain information about the participant's perception of certain frequencies and other musical/melodic features. Although we are essentially 'testing' this in participants we were particularly conscious of the fact that we did not want the participants to feel as if this was an examination or that there was any pressure on them to answer 'correctly'. On the contrary, we specifically wanted people to answer and comment on *their* perception of the music without regard for whether their answers were 'correct' or not.

As a result we commenced this part of the session by giving the participants a chance to listen to various different versions of familiar music; the presentations of such familiar melodies would be based on a model of continually increasing complexity (more details below). After hearing each version of the music, participants were asked to comment on how the music sounded *to them* via their implant. This decision was made because the answers to our questions should be subjective and personal as there are no 'correct' answers; only the opportunity to comment on the personal music listening experience. The rating that each participant gave although not identical to the others in the group were equally valid and interesting for the purposes of the current research and for the interest of the group in general.

Participants rated, by means of a seven-point Likert scale, how various versions of familiar tunes (each version more complex than the previous) sound via their implant. The melodies that we selected to present to the participants were 'When the Saints go Marching In' and 'Yankee Doodle', which were both familiar to the participants. When planning the session, we knew that there would be at least two musicians available to present these melodies (and their increasingly complex derivatives) so a scheme was devised that would help to structure the presentation of the chosen melodies on saxophone and keyboard (see appendix A for an example). This suggests a structure by which a familiar melody can be played in various ways, each more complex than the previous. Structuring the presentation of music in this way allowed us to question CIUs on incremental changes to the rhythmic, harmonic and melodic complexity of the music and receive feedback relating to the effect of such changes on the perception and listening experience.[3]

The second set of music listening questions developed for this group was a melody identification exercise. It was decided, due to time restrictions that this would be conducted as a closed-set identification exercise where participants were presented with a written list of song titles and the title of each piece of music played during this part of the session. [4] When the music is played, participants had to select the title of the song from this closed-set of titles. If participants were able to associate the melody with it's title then this suggests that they have some degree of music recognition abilities.

Although it was not the case for this session, an exercise of this nature could be developed, for those users who are continually able to identify the song, by altering the melodies in some way and asking participants to identify how and where the melody was changed. This can be achieved in a number of different ways, examples of which can be seen below. Figure 2.1 (below), for example, shows the traditional Scottish song 'Auld Lang Syne' in two different forms. The upper line is a representation of the 'original' melody of the song that most people would recognise, whereas the lower line shows each note of the melody represented as a crotchet, regardless of it's duration in the original version.


Figure 2.1: Auld Lang Syne  Potential Variation 1

Although many normal hearers may be able to recognise this altered version of the

[3]From a logistical perspective, a presentation structure such as this one can be extended or compressed according to the time available during the session for an exercise of this nature. Thus, the music could be made more complex in many different ways, meaning that the possibilities for exploring the effects of different elements of increased musical complexity are vast - those presented in appendix A are merely suggestions.

[4]Prior to starting this exercise, participants had the opportunity to inform the organisers if they are unfamiliar with any of these melodies  if so, these will be removed from the set.

song, it may be potentially more difficult for some CIUs as the isochronous nature of the altered melody removes rhythmic cues, which may also be used by CIUs in the process of identifying music.

Another example of an altered melody could be based on creating deviations from the expectations of the CIUs. Figure 2.2 (below) again shows the melody of ‘Auld Lang Syne’ in the top line and an altered version of this melody in the lower. Although the melody in each line looks very similar, the fourth full bar after the anacrusis shows a difference between the two. The note, which we expect to be a D, based on our expectations of the melody, is (in the lower part) presented as an F and is therefore a deviation from the melody known by those who are familiar with the song.


Figure 2.2: Auld Lang Syne Potential Variation 1

Presenting music with deviations to the expected melody, whether very obvious or subtler such as the example above is also a very useful way to investigate how well melodies are being perceived as: (a) participants can be asked to decide whether or not the melody was altered and, (b) can be questioned with regard to which part of the melody was different and in what way had it been changed. Again, please note that this was not used during the session described in this chapter but is presented as an idea drawn from the current research for future work of this nature.

## 2.3 Live Music Evaluation

When planning this group we were aware that the process of music evaluation in a session of this nature is potentially problematic. This might relate to practical/logistical problems including; financial restraints (employing musicians can be expensive), lack of available competent musicians, lack of musical knowledge required to suitably direct musicians, for example. In our case, we know that there would be two available musicians so many of these issues were avoided.; in general terms, however, I believe live music to be an important element of music listening and, therefore, something that should be included in group sessions of this nature if at all possible. Additionally, providing this type of evaluation as a live music listening experience was hypothesised to make it even more valuable because, in addition to hearing the music, participants were able to watch the sounds being produced by the musicians and therefore experienced two musical instruments being played live. This provided the opportunity for participants to comment on the effect of the music becoming more complex with each rendition of the music and also meant that they were asked about the sound of the instruments and the nature of their music listening experience having heard and seen the instruments being played live. Essentially, one of the main benefits of having live music played at sessions of this nature is that it allows the organisers to question the CIUs about the effect of the live performance on the general musical experience and also gives the opportunity to observe and gauge the effect that this has on the participants' perception of the music.

My experience of using live music with this type of group highlighted something interesting with regard to the ratings that participants give to the sound of the music. As we were performing live for the group it was obvious, based on body language and facial expressions, that one participant, in particular, was not enjoying the way that the music sounded. However, when asked how she felt about it she told us, emphatically, that she really enjoyed it. When we questioned her further about this and mentioned that we noticed her covering the microphone on her implant and reaching to turn the volume down she admitted that she did not like the sound and that it was painful for her to listen to but didn't want to be rude or offend us by saying that about 'our music'.

Obviously, in this case, the participant felt obliged to give a favourable evaluation of the live music listening experience in order to be 'polite' to the musicians that were performing. This is an example of how the social situation in which the musical experience took place and the set of rules which surrounds this situation impacted on the way a participant reacted in response to music. In retrospect, if we had explained to the group prior to this exercise, that the musicians are not present for the purposes of giving a concert and that the music that they will be playing is only meant to be a way to provide short samples of certain musical elements may have prevented such issues. This was a valuable lesson as it has taught me that, for future work (as discussed in subsequent chapters), it is important to be explicit and inform the group that they should not feel awkward or uncomfortable talking about the way that they experience live music. In addition, with this potential problem in mind, I realised that it would be important to pay particular attention to the body language of participants, as the music may be uncomfortable and it may not be sufficient to rely on *them* to inform you of any such problems.

## 2.4 Recorded Music Evaluation

The most frequent music listening experience in western society is that of recorded music, i.e. CD, vinyl, MP3, tape, for example, thus we included this experience as part of the focus group for the benefit of the participants and to gain first-hand information on music presented in this way. In selecting the stimuli for this section of the group, no consideration was given to whether or not the music presented to the participants would be familiar. Although we were interested in the participant's attitude towards familiar and non-familiar music, respectively, this did not influence our choices of stimuli in the first instance. However, participants were asked (when rating the sound of the music via their implants) to indicate whether or not the music was familiar to them.

It was decided (due to time considerations) that for this section of the session we would give participants the opportunity to hear and evaluate three songs presented via CD. With these three pieces of music we wanted to present a range of musical styles in order to stimulate discussion about the way that music listening experiences may change as a result of stylistic differences. Additionally, from a practical point of view, this was also influenced by the recordings that we had available to us. With this in mind, the stimuli selected were as follows:

(a) 'I Walk the Line' performed by Johnny Cash (Cash, 2002)

(b) 'City of New Orleans' performed by Arlo Guthrie (Guthrie, 1990)

(c) 'Oops, I Did it Again (cover, originally Britney Spears) performed by Richard Thompson (Thompson, 2006)

After each song was presented, participants were asked to state if the music was familiar to them and to rate (by means of a seven-point Likert-style Scale) the sound of the music via their implants. It was made extremely clear that we were not asking for opinions based on musical taste or whether the song/performance was enjoyable to them as individuals, for example, comments were to relate only to the way that the music sounded and their feelings on this matter. Printed lyrics were provided for each song so that participants would be able to follow the music without having to concentrate excessively on the verbal content, thus avoiding potentially distracting them from the process of evaluating the sound of the recorded music.

After all the participants had rated the sound of a track and indicated whether it was familiar or not, each member of the group was invited to comment on their personal listening experience. If, for any reason, participants found it difficult to communicate their opinions, one of the group organisers could ask some general questions in order to prompt a response. As always, participants were never forced to talk in front of the rest of the group if they did not want to but they were actively encouraged to do so for the benefit of all present. Fortunately my experience of this group was a positive one in which all the participants were eager to share and discuss their thoughts and feelings on their implant mediated music listening experiences.

Using CDs or other digital audio sources (mini-disc, .wav/.mp3 files, for example) is particularly sensible as: (a) it is easy and relatively inexpensive to play music from recorded media; (b) this type of performance can be paused, stopped/restarted, can have the volume accurately and reliably adjusted; (c) it will be played in *exactly* the same way each time, something that cannot be guaranteed from live musicians; (d) it is far easier and more practical to present a multitude of different genres/styles of recorded music than to with live musicians.

The presentation of different styles of music gives the opportunity to explore the way that CIUs experience different styles of musical composition, performance, instrumentation and production, for example. Being exposed to genres and styles that may be unfamiliar to them or that they may not have chosen to listen to prior to implantation may be a useful and illuminating experience for some CIUs. That is to say that many people may not realise that any difficulties in listening to the music they chose to listen to (pre-implantation) are not necessarily representative of the music listening experiences in a general sense. If CIUs find that their favourite type of music, for example, is no longer pleasing to listen to since receiving their implant, this could be the result of a multitude of factors some of which (e.g. orchestration, production), may not be as problematic in other styles of music. Therefore, providing a broad cross-section of musical styles in group sessions is something that could provide interesting insight for CIUs. This can serve to provide them with the opportunity to be exposed to music that may be completely alien to them in a supportive environment in which they have access to the advice of musicians/rehabilitation-specialists, in addition to the other participants and family members. Attempting to make participants aware of other musical styles that, as a result of their musical/acoustical character, may be more suited to the needs of CIUs could be beneficial to their future musical experiences.

With regard to this particular group, the participants noted that the song that they preferred was ‘I Walk the Line’, by Johnny Cash (ibid.). One participant, who said that it was nice to be able to listen to a record and hear a singers voice clearly without other instruments or noises *’getting in the way’*, described this song as the least ‘noisy’ of the three. The same participant also noted that they knew this song well and greatly enjoyed listening to it. In general there was a positive response to the recorded music listening task and the participants reported that they had enjoyed listening to the music but unanimously stated that, since receiving their implants, they have to concentrate a great deal more than they used to when listening to music. This was said to be ’off-putting’ and that sometimes the effort was not worth the reward of listening to the music, as it often ‘didn’t sound right’ or that certain elements of the recording or performance were ‘distracting’. A very interesting comment from one of the participants was that they wished they could get rid of the sound of certain instruments when they listen to music or that they wish they could increase the level of the singer’s voice, for example. This was extremely interesting to me and this idea has become a central theme throughout this thesis, (see chapters 4 & 5).

**Audiovisual Music Performance Evaluation:**

In addition to providing participants with the opportunity to experience and evaluate live and recorded music, it was decided that providing the chance to watch DVD recordings of live musical performances would be valuable to the participants and that comments on this experience could be very interesting from a research perspective.

Audiovisual recordings of live music performances (concerts/studio recordings etc.) have obvious benefits for CIU participants as this type of presentation facilitates the simultaneous reception of the auditory signal and also provides visual cues. In the case of CIUs who are known to have less accurate access to the spectral features of music, the addition of the visual cues to the music signal can serve to contextualise the sounds that they are hearing. For example, the sound of a violin playing in a band is something that is often reported as a problematic sound or, at least, one that can be confusing and cause difficulties in perceiving the other instruments in the mix. However, if this sound is supported by a visual representation of the way the sound is being produced then the CIU could potentially have more chance of understanding the source of the difficult signal and thus deal with it by deliberately attending to it or otherwise, for example. This can be reassuring and instructive to the participants as, if they are having difficulties perceiving certain elements of the music, they will not simply perceive a musical signal that is distorted by this element but will perceive the same signal with the support of moving images of this sound being produced. Therefore, they have the ability to associate the problematic sound with a visual representation of the instrument and can, in this way, make an educated decision to avoid this instrument in future or try to deal with it in other musical contexts.

With regard to format, DVDs are perhaps the best way to present performances of this nature, for a number of practical reasons. The most important of these reasons is that the sound quality of DVDs (i.e. a digital source) is generally far superior, in terms of clarity and noise reduction to VHS or other analogue formats. In addition, some DVDs have the ability to toggle the presence of subtitles so that participants can watch the performance and have the lyrics on the same screen, thus reducing the extent to which they have to concentrate on deciphering the lyrics from the recording or focus on a separate lyric sheet. Also, in some cases it is possible to select between a number of camera angles which can be useful for CIUs as they may wish to have a better view of the singers face in order to facilitate lip reading or to have a clearer picture of a musician playing a particular instrument in order to contextualise the source of the sound in the way described above, for example.

As with the selection of recorded music the selection of stimuli was influenced by what that which was available to us and although the participant's familiarity with the music was not a concern during the stimuli selection process, it was decided that we would select music that was likely to be well perceived (not overly complex music with regard to orchestration/mix, for example), based on general knowledge of the music perception abilities of CIUs (see chapter 1). This decision was made as we did not want to provide any material that would be too challenging in this kind of session, in the interests of providing an encouraging and interesting experience. If this session was followed up by future groups or one-to-one contact time, more challenging material could be dealt and explored more meaningfully, however, in the focus group setting it was our intention to create a supportive atmosphere that would encourage participants to engage in music and incorporate this into their aural rehabilitation programme.

Other considerations taken when selecting the audiovisual stimuli to present related to elements such as vocal clarity, lip-reading potential, mix, orchestration, availability of subtitles and the sung language. Based on these considerations the songs chosen to present to the participants were as follows:

1. Don't Dream it's Over  by Neil Finn (Finn, 2002)

2. The Good Man  by Kate Rusby (Rusby, 2004)

3. Erie Canal  by Bruce Springsteen with The Sessions Band (Springsteen, 2006)

4. Country Roads  by John Denver (Denver, 1999)

5. San Francisco Bay Blues  by Eric Clapton (Clapton, 1998)

The two recordings that were most highly favoured by the participants were 'Don't Dream it's Over' by Neil Finn and 'Country Roads' by John Denver. Participants stated that the former was particularly appealing as it was a recording of just Finn singing and playing the guitar, both of which could be seen and heard clearly. The fact that there were only two elements to the signal and that the guitar was played as an accompaniment to the signing meant that it was easier for the participants to perceive and comprehend the music as a whole and to make out the words and melody. One participant noted that he recognised the song and was able to state that it was originally recorded by the band Crowded House (the band which Neil Finn played with).

With regard to the latter, participants stated that this was a favourite as the image was shot so that the camera was almost always focussed on Denver's face which gave a clear view of his lips and facial expression, largely unobstructed by the microphone. Although the orchestration of this performance was much more dense, the band were relatively low in the mix compared to the lead singer which was pleasing to the participants as this, coupled with the clear view of his lip and face and the subtitles on the DVD, meant that they were able to recognise and enjoy the song via this live recording. In addition, the song was 'Country Roads' which is very famous and popular throughout America meaning that they had some pre-implantation knowledge of it.

Despite enjoying the DVD performances and appreciating the addition of the visual aspect of the performance, participants noted that they were still aware of having to concentrate on the music a great deal, as was reported with regard to music listening in general (above). One participant pointed out that the reason he seemed to particularly enjoy the two pieces of music noted above was that during these he felt that he had to concentrate less and was, therefore, able to relax and enjoy the performance. As a result he stated that this had been an eye-opener for him and that he would be more conscious of this when selecting music for recreation in future; he did not state what music he might opt for in future, however.

Providing the opportunity for reflection and discussion is led to the aforementioned participant contemplating his realisation with regard to his future music choice, for example, which suggests that this section of the group has been interesting and informative for participants and researchers/organisers alike.

## 2.5 Music Groups for Paediatric CIUs

When considering music groups for adult CIUs (above) the reason for running and the focuses of such groups were twofold, namely: (a) to explore musical experiences in a supportive and safe environment; and (b) as a direct way to research the music perception abilities and listening experiences of adult CIUs. As was noted, one way to do this is to structure the session as a focus group with the explicit yet general focal point being ‘Music’, thus suggesting that the purpose of the session is to find out about people’s views and feelings on this subject. In addition, this type of structure is a way of avoiding the potential difficulties or anxieties that may be associated with providing any kind of ‘investigation’ around the area of music. Whether or not this is an overt strategy for adult groups is the decision of the organisers, however, when dealing with music groups for children, particularly child CIUs, the primary focus should be on enjoyment and fun with any research interests being secondary and concealed so that the participants do not feel as if they are being tested. When planning the four-day music group for children, during my internship at the HRF, this ideology was adhered to strictly in the interests of creating a fun and engaging environment for the child-participants.

With regard to the focus of this type of group, the idea of mutual learning is perhaps even more important as groups of this nature can serve as extremely valuable opportunities for children to begin to experience music in a safe and supportive environment and can also be used as an opportunity for observational research into the music experiences of paediatric CIUs.

In planning the children's group we set out with the belief that each child should be given every opportunity to be involved in all activities and should be actively encouraged to take part in all aspects of the group. However, if any of the participants were anxious or nervous of a certain element of the group or activity they should be encouraged to try to participate or have the instructions explained to them again in case their reticence is due to a lack of understanding. As fun is one of the primary focuses for this group, we believed that the child's experience should not be marred by feelings of nervousness, pressure or inadequacy, for example. Conversely, however, those participants who may be dominant members of the group or those who are particularly excited should be encouraged to observe 'good manners' and other social conventions such as 'turn-taking', listening to others and adhering to the rules and ethos of the group.

### 2.5.1 Participants

Due to our insistence for the primary focus of these sessions to be on fun and enjoyment, formal investigative research should be a secondary consideration that does not interfere with the presentation of music and the running of activities. It is less important to try to construct a contrived research group that is balanced accurately for age, speech perception/production abilities, for example. However, the ability to communicate aurally in a group situation is very important as interaction and, in turn, participation could be compromised if the participants do not have the necessary level of communication abilities to function adequately within a group situation. Again, it is not unreasonable for the purposes of participant selection to presume that those CIUs who have achieved a level of speech perception sufficient for communication in a group setting have enough implant experience to provide reliable evaluations of the sounds they are hearing.

The issue of pre-implantation memory of music was not one that was addressed when we were determining the criterion for participants in the children's music groups. The main reason for this decision was that the type of activities that we would arrange for children would not require them to compare recent/current experiences of music with any pre-implantation memories. Additionally, when dealing with children in this age group it is obvious that they will not have had a great deal of pre-implantation experience with music so comparisons of this nature are not particularly meaningful in this context.

As with the adult groups, the number of participants was another consideration that could influence the ability of the group members to communicate aurally and, in turn, could determine the success of the group. Again, too large a group could lead to increased background noise, thus making communication amongst the group more difficult and, in the case of children's groups particularly, could lead to diminished concentration and encourage infantile behaviour amongst the participants. Although fun is one of the primary objectives, the group needs to be controllable and attentive to the instructions of the organisers in order for the activities to run smoothly and have the desired effect/experience for the participants.

As the participants recruited for this group (volunteers in response to adverts) were children around the ages of five and six we decided that it would be sensible, if not imperative, for the children's parents/guardians to remain at the sessions in case of any problems. Also, allowing parents to be present would hopefully encourage them to try to use some of the music activities at home by way of including music listening/participation exercises in their general rehabilitation programme. In this way, the sessions may be instructive or inspirational to the parents and they would have the opportunity to discuss any of the methods or materials with us before attempting to use them at home with their CIU children or, indeed their NH siblings and friends. Based on Plant's prior experience of dealing with implanted children and consideration of resources and space available to us it was decided that we would limit the number of active participants in the group to five.

By encouraging parents to be present at the groups (which took place during the summer holidays) it meant that, in many cases, they had to bring their other children. Again, we believed this to be positive as it meant that the siblings would have the opportunity to learn about the activities thus making it even easier to incorporate them into play and learning at home. However, it was extremely important when dealing with these children that the parents and siblings do not become too involved in the group. This may be distracting for the active participants and unnecessary input from the parents or siblings may undermine the position of the group organisers and lead to problems in communicating instructions or in the participants' concentration levels and that, in turn, participation may become diminished.

### 2.5.2 Participant Introductions

Another benefit of running participative music groups with paediatric CIUs is that it can encourage the development of social skills such as 'turn-taking' and listening to peers or organisers, for example. Although, as suggested above, children are less likely to feel anxious in a group setting than adults, it is important that some consideration is given to the fact that some may feel nervous or uneasy in this situation. As a result, we began the group session with an 'icebreaker' activity that would help the participants to feel comfortable and to build familiarity within the group. We decided that an interesting and fun way to begin the group which encourages turn taking, appropriate/polite group behaviour and attention to rhythm would be for each member of the group to introduce themselves by stating their name in accordance with a rhythmic scheme built up within the group. Figure 2.3 (below) shows two rhythm lines; the upper being the way the child might say and clap their name (in this instance, the name Cameron) with the lower showing the prevailing pulse which will be determined by the other members of the group. Please note that this example is in common time meaning that the greatest rhythmic stress falls on the first beat of each bar. The first bar can bee seen as a 'count-in', which is used to make the child familiar with the beat and tempo of the exercise, i.e. to let them know how quickly the beats are progressing and where the rhythmic stress is in any given bar; this can be achieved by repeating this bar until the group are aware of and comfortable with the pulse.

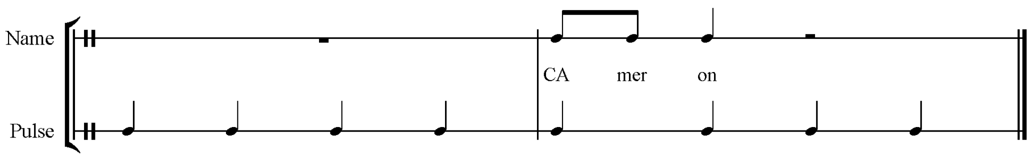



Figure 2.3: Rhythmic Participant Introductions  Cameron

As we can see from this example, the name Cameron is spread over two beats with the first syllable (capitalised) falling on the downbeat. This mirrors the way that the name Cameron is likely be pronounced, with the most stressed part of the word being the first syllable; e.g **CA** mer- on as opposed to ca **MER** on or ca - mer **ON**. Therefore, we would encourage children to try to incorporate the rhythmic features (e.g. beats and stress) of the prevailing pulse when trying to pronounce their names rhythmically. Clapping the prevailing pulse as a group for a period of time, making a particular feature of the accented nature of the first beat in a common time bar, before asking children to clap and say their names will help to establish the idea of the first beat of a bar having the greatest stress. Figure 2.4 (below) shows another example which suggests a possible appropriate rhythmic presentation of the name Elizabeth.

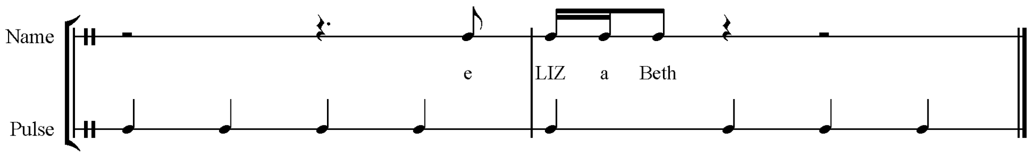



Figure 2.4: Rhythmic Participant Introductions Elizabeth

As we can see from this example this name does not start on the first beat of the bar but rather on last quaver of the previous bar (i.e. the back of beat four). Again, this mirrors the way that the name Elizabeth would be pronounced i.e. e **LIZ** a beth, as opposed to **E** liz a beth, or e liz a **BETH**, for example. Therefore, by placing the first syllable of the word on the back of beat four, this allows for the stressed second syllable **LIZ** to be pronounced on the first beat of the bar meaning that the rhythmic and syllabic stress are matched.

This type of exercise was included in this session as it encourages children to think about the natural stresses of syllables in words and to consider the way that such prosodic elements can be similar to the rhythmic division of music or the dominance of some beats over others due to their temporal position in a bar or phrase. When conducting exercises such as this it is important to get each participant to consider their name and it's 'rhythm' individually but to have the rest of the group mirror each other's name in the same rhythmic manner as it was presented. This will encourage 'turn-taking' and listening to others. Also, the repetition will help to enforce the rules to the group and facilitate the memorisation of the names of the other participants. In addition to this being used as a way to develop the regularity and rhythmicity of speech and encourage

’turn-taking’, it can also be used as a fist step in helping children to understand rhythm in music and to aid the teaching of rhythm and reading written rhythms.

This simple activity was a good way to begin the group due to it’s obvious social function of introducing each member of the group, one-by-one, but was also very appealing to the children as it relates rhythmic elements of music to them personally by including *their* names in the exercise/game.

### 2.5.3 Group Discussion on Music

Having let each member of the group introduce themselves and allowed time for the group to learn each other’s names in a fun and engaging way, the participants began to feel more comfortable around each other. In anticipation of this, it was decided that after the introductions we would, as with the adult group, allow the session to be opened up for an open group discussion on music and the musical experiences of the participants.

Again, as with the adult groups, it was important that the participants did not feel as if this type of exercise was a test or that the answers that that they gave could be considered ’right’ or ’wrong’. Instead, general questions were asked to the group as a whole as a way of stimulating discussion amongst the participants. The children were informed that we wanted to know that how they felt about music in general and were told unequivocally that this was not any form of exam but rather, simply a way for us to find out how they felt about music. For children, no distinction was made between ideas of perception and experience and we were careful, at this stage in the group, not to draw too much attention to the fact that we were interested in the effect that their CIs had on their impression or enjoyment of music. Again, it was decided that if time permitted any parents/guardians that were present and willing to talk would have the opportunity to speak about any feelings or observations that had about the way that their children use, engage with and enjoy music. Information of this nature would be very useful but this opportunity would only be afforded if it seemed appropriate to the mood and dynamic of the group, i.e. if parental contributions would not be too distracting (or even boring) for the children.

Although this discussion was to be as open and participant-led as possible it was important for one of the organisers to act as a ’chairperson’ for the group. The designation of a chairperson ensured that the discussion stays on course and did not become an opportunity for the children to behave inappropriately and allowed for the prompting of the children on certain topics in order to stimulate responses from the participants. This is a role that may be more important in children's groups if the participants are shy or reluctant to talk in a group setting, however, as with the adult group no one was forced to talk but those who do not contribute to the group discussion were prompted directly and asked specific questions as a way to gain information and also to encourage them to speak in front of the other participants.

Within the group there was a range of language ability and, as would be expected, confidence levels. Notably, one young girl was from a Chinese family who spoke in both Cantonese and English at home. As a result, she was less able to contribute to all areas of the conversation due to minor language problems - confidence was not an issue, however and she was very keen to be an active member of the group. One young boy was particularly confident and very excitable and had to be managed carefully by the 'chairperson' in order to avoid him completely dominating the group. Despite minor issues such as these, the group discussion proved valuable for the members of the group and interesting from a research perspective as the groups' comments were very positive with regard to their musical experience.

### 2.5.4 Songs

When selecting the songs that would be used during the children's groups, it was decided that we would use three categories of children's songs which may be categorised as follows; 'action songs', 'narrative songs' and 'accumulative story songs'.

#### Action Songs

Action songs (also known as, activity songs) are simple, often repetitive songs that either have a set of actions associated with them or songs that have instructions relating to physical actions, provided by the lyrics. Examples of such songs include such children's songs as 'The Wheels on the Bus' or the 'Hokey Cokey' which have repetitive structures with physical actions that are either associated with the song and it's lyrics, as in the former or songs with lyrics that contain explicit instructions on how to participate with the song. Songs of this nature can be a valuable part of childhood education as they can provide an opportunity for young children to experience music physically in a way that is engaging and fun, incorporating play and dance, in some cases.

Action songs have potential benefits for paediatric CIUs and can also be useful assessment or research tools for parents, teachers and aural rehabilitation specialists. They provide the opportunity for children to participate even if they do not know or are unable to sing all the words, a benefit for most children but, obviously something that can be particularly useful for children with audition or communication difficulties such as paediatric CIUs. The ability to participate despite such difficulties or problems can be of tremendous benefit to their self-esteem and social development and can facilitate rhythmic movement and expression in a fun and non-threatening way. In addition, it is presumed that continued participation in activities such as this can develop listening and concentration skills and, in turn, serve to increase attention span.

From a social and educational point of view, action songs are also useful as they can be used to promote the idea of listening carefully and following verbal instructions in the way described by the song lyrics. In addition, some action songs also afford opportunities for self-expression in the way that they carry out the instructions, encouraging personal responses in the way they use their body to execute the instructions presented in the songs lyrics or suggested by their themes and topics. An additional benefit of action songs for paediatric CIUs is that by concentrating on the actions associated with the song, children can be somewhat distracted from the realisation that they are singing in a group, something which older children may feel anxious about doing.

From a research or assessment perspective, we can use action songs as a way to observe how well the children are actually hearing the lyrics (action-instructions) of the song, providing us with an indication of their perception and comprehension. This is particularly apparent in those action songs that contain explicit instructions in the lyrics.

During the preparation for the children's music groups it was decided that we would use songs that were potentially familiar to the participants in order to make them feel more comfortable in the group situation and that we would also write new action songs that could be taught to the group. One of the songs that was written in preparation for the children's groups was called 'I Can Clap My Hands' which is outlined below:


Figure 2.5: I Can Clap My Hands Verse  Action Song

As shown by the example above, this piece is written in a simple format whereby the narrative voice informs the listener that they can perform a certain action (clap hands in the example above), then states that someone else (others) can also perform this action before going on to state that both the speaker and the other can perform this action together. This format means that the action participants are instructed to do is repeated four times giving a great deal of opportunity to be perceived, comprehended and obeyed. Other actions include; blink my eyes, nod my head, jump up high, wave hello, crouch down low, shout goodbye, for example.

From a musical point of view, this piece was written as a way to make participants familiar with sound of the major scale and major scale harmony. As can be seen from the example above, the melody contains only notes from the key of C major and, in many cases (e.g. bars 1 and 4), is made up of sections of the scale. The harmony is also entirely diatonic making very obvious use of the tonic and dominant chords to enforce the sound of the key in which the music is written. A similar song was written for the group called 'Here is What You Gotta Do', in which the participants were also given instructions. In this case, the instructions were more open to interpretation as they included such actions as 'jump just like a kangaroo' or 'buzz just like a bumblebee', for example. This song provided even more opportunity for the children to move around the room and interpret the prescribed actions in their own way  something that was particularly enjoyable for all involved.

Importantly, the children all enjoyed the activity songs a great deal and enjoyed participating in the song physically and vocally, something that was (as we discovered during the session) not a usual occurrence for them. As a result of enjoying the activity, the children would arrive at subsequent sessions and specifically ask to sing these songs and by the end of the week, most of the children knew all the lyrics and actions. This serves as evidence of the fact that they had a positive musical experience and further supports the suggestion that musical experience can be derived from far more than the acoustic signal alone. In the case of the action songs used in this group, the children also enjoyed the combination of physical and aural participation which I believe to have contributed to their positive experience and the fact their desire to use these songs at each session.

**Narrative Songs:**

Narrative songs, are songs that either present a story by way of a narrative or in a accumulative sense such as ‘There Was an Old Woman’, and are appealing to both child participants and adult researchers/therapists for many of the same reasons as other types of songs. For the participants the appealing musical and participative elements of songs remain present but the songs lyrics can be used to tell a story, an additional level that can make the song more enjoyable for many participants.

From a research and observation perspective, songs of this nature can be particularly useful as the story presented by the lyrics can be a simple starting point from which a discussion can be stimulated about elements of the song such as theme, plot, characters, events and even specific detailed discussion about the lyrics and their meaning, for example. Discussions generated by asking the children about elements of the song such as the setting or the plot, for instance, proved to be another interesting way in which the song served as a way to probe the perception abilities of the participants. In the case of action songs (above) it could be conceived that even if the children were unable to accurately perceive, understand and execute the instructions presented in the lyrics, that they might be able to feign comprehension by imitating the actions of their peers. However, in the case of story songs it is less likely that children can conceal any miscomprehension as the way that they answer questions and participate in discussion about the song and it’s lyrics, for example, may reveal any problems in perception or understanding.

Another of the songs that we wrote in preparation for the children’s group was called ‘The School Bus Blues’ which was based on the melody of an American folk song ‘The Midnight Special’. This song tells the story, in the first person, of a child who is running late for school and is rushing to be ready for the school bus arriving. The song outlines the events between waking up and arriving at school, such as having breakfast, brushing your hair, leaving the house, waiting at the bus stop to find that the bus is actually late and that all the children, having rushed to get ready for school are standing in the rain waiting on the bus. The events of the song are all things that the children can relate to and can form interesting starting points for discussion about the song and their own experiences of such events.

A development of this type of exercise for use with older children would be to give the participants the chance to write the lyrics of the song based on a melody and a given topic or to write verses around a pre-written chorus, for example. Developing the exercise in this way gives the participants the chance to participate in the writing of the song/story, something that may be more interesting for older children and that gives the participants a sense that they are involved in the composition process.

Exercises such as those outlined above may also be suitable for adult groups, however, appropriate material should be chosen so that adult participants do not feel patronised by such an exercise. In this case, the model of increasing complexity may also be applied by repeating the exercise over a period of time and each time selecting music that is more complex. This complexity may be derived from the relative prominence of the vocals in the mix, the orchestration (i.e. the amount of other instruments playing at the same time as the vocal), the speed and clarity of the vocal performance, the diction of the vocalist, for example.

**Accumulative Story Songs:**

The description ‘accumulative story songs’ refers to songs in which a story is told by each new verse or stanza with an accumulative effect being created by the repetition of the whole story, before each new verse is added. Once a verse has been added it becomes part of the song and the whole story or a simple version of it (including the most recently added verse) needs to be repeated before the next verse is added. This next verse will then become a part of the song leading to a progressive form that is constantly expanding to incorporate new material in a cumulative manner. For example, this type of song may be structured as follows:

Verse/stanza$^a$, $Verse/stanza^{a+b}$, $Verse/stanza^{a+b+c}$, $Versestanza^{a+b+c+d} etc.$

Some common examples of ‘accumulative story songs’ are ‘The Rattlin’ Bog’, ‘The Twelve Days of Christmas’ and, perhaps the most common being, ‘There was an Old Woman who Swallowed a Fly’. In this particular song we see a cumulative story in which an ‘old woman’ swallows a fly for reasons unbeknownst to the narrative voice. In a series of concatenated verses, this cumulative story song describes a multitude of other creatures that the ‘old woman’ swallows in order to catch the previously swallowed creature. For example, towards the end of the song we have learned that:

| | |
|---|---|
| *‘There was an old woman who swallowed a cow,<br>I don’t know why she swallowed a cow!* | Most Recently added verse/stanza |
| *She swallowed the cow to catch the goat,<br>She swallowed the goat to catch the dog,<br>She swallowed the dog to catch the cat,<br>She swallowed the cat to catch the bird,<br>She swallowed the bird to catch the spider,<br>She swallowed the spider to catch the fly,* | Abbreviated versions of previously added verses/stanzas |
| *I don’t know why she swallowed the fly,<br>…perhaps she’ll die!’* | Chorus derived from verse/stanza[a] |

Figure 2.6: Accumulative story song structure

From the example above we can see how this type of song tells a story cumulatively by continually adding new stanzas or verses to the expanding body of the text. Songs like this can be particularly appealing to children for a number of reasons such as: (a) they require less memorisation of lyrics since the repeating nature of the cumulative structure means that, as the song progresses, they are already aware of a great deal of the song’s lyrics as they have sung them in previous verses; (b) The act of memorising and singing the lyrics and their order and structure can be like a game to the children; (c) the repetitiveness of the verses helps them to learn the story and facilitates group participation; for example.

For the reasons noted above, it was decided that we would include an activity whereby the children were able to participate in this type of activity, in addition songs of this nature could be developed so that the children were also able to participate musically.

The ‘accumulative story song’ that was selected to use with this group was called ‘There was an Old Lady who Swallowed a Trout’ (Sloat, 2002), a variation of ‘There Was an Old Woman Who Swallowed a Fly’, which is set in the Pacific Northwest of North America. This activity was started by firstly reading the book to the group whilst showing them the colourful pictures, something that also served as a starting point for discussion. The children, who all knew of the song 'There Was an Old Woman Who Swallowed a Fly', were very interested in this story/song as it was similar to the song they already knew but talked about animals such as trout, salmon, otter, seal, porpoise, walrus, whale and eventually concluded in the old lady swallowing the whole Ocean. After having discussed the story with the children and allowed them to talk about their impressions of it we asked them about the sounds that may be made by the events of this story. This was particularly interesting as, in this version of the story the old lady swallows a trout 'which splished and splashed and thrashed about. It wanted out!' (ibid.). Such onomatopoeic language proved to be effective stimuli for the children who echoed the sounds and actions described in the book. Following this we asked the children to select one of the instruments or 'sound-makers' (see below) from the selection available to represent the sound or character of each element of the story mentioned. Each child (and group organiser) was given this opportunity so that each animal in the story had an instrument or sound associated with it, e.g. trout = shaker, otter = small hand-drum, for example. Following this selection process the children were given instructions to play their sound only when their animal was mentioned. This meant that each time an animal and it's action was mentioned, as the story was being read/sung, the child who had this animal assigned to them would create the appropriate sound based on the instrument that they had selected to represent the animal.

This activity was very useful for both participants and organisers as it was one that was enjoyed greatly by all involved. In addition to the points noted above regarding the benefit of this type of song, the addition of the instruments and sounds as representations for the animals and there actions made this type of activity beneficial to the participants for two main reasons. Firstly, the children self-select the instruments/sound-makers that they believed represented the animal in question and it's actions. This involves the children considering the nature of sound and the effect that physical action has, coupled with the process of experimenting with the sound of instruments and making a decision as to whether this sound was appropriate. This is involves a great deal of imagination and listening and is a good way to get CIUs of this age to think about the character of sound and how it is produced. Secondly, the children have to attend to the story, listening specifically for the animal that they have been asked to represent and then make their sound at the appropriate time. This encourages the children to listen to and concentrate on what someone is saying, a basic social skill that can sometimes be problematic for children with specific problems of this nature. In addition, it also encourages and provides practice of turn-taking which is a very important part of conversation, group music making and communication in general.

This activity could be developed for older children or children who have learned to play a musical instrument by using leitmotifs for each of the characters in a story, such as in Prokofiev's 'Peter and the Wolf' (1936). These could be prewritten or could be composed/improvised by the children as part of the group activities once they know and are familiar with the story with which they will perform their music and sounds. This could also be achieved with younger children if they were able to attend music groups or (re)habilitation groups focused on music on a regular basis.

Again, as with the activity songs, the children thoroughly enjoyed both forms of story song. The accumulative form was particularly appealing as it can be conceived of as a game in which the participants have to memorise all the verses/stanzas and repeat them as quickly as possible without forgetting or stammering on the lyrics. This is a very positive outcome as it is proof of music being used to practice the speech and listening skills of paediatric CIUs, whilst remaining fun and enjoyable. The inclusion of music and sounds in the accumulative story was also something that was greatly enjoyed by the children and something that was managed successfully by most. However, the children who were assigned an animal/sound that did not appear until nearer the end of the story showed more difficulty in playing their sound at the appropriate point. This could be due to the fact that, since the story is cumulative, the amount of sounds being produced by other participants increases as the story progresses, thus creating a level of background noise that made hearing the speaker difficult. The increased levels of noise and activity throughout the story could also have been a distraction to the children so that their turn was missed due to a lack of concentration on the vocal cues.

### 2.5.5 Sound-Makers:

In addition to providing the opportunity for child participants to listen to music and participate by singing songs or providing the accompanying actions, another important activity that could facilitate participation and musical behaviour is to introduce the children to the use of musical instruments. Giving participants the option to participate in collective music-making using means of musical sound production other than their own voice is a strategy that is particularly useful and interesting for both participants and researchers/practitioners alike. From the participants‘ point of view it allows them to express themselves musically without relying on their own voice. Additionally, children often find musical instruments interesting and appealing, regardless of whether they have the required skills to operate the instrument appropriately. However, in the context of this group, the ability to play the instrument ‘properly’ is irrelevant as the purpose is to allow children to experiment with the relationships between their physical actions and the sound produced by the musical instrument. When playing with musical instruments, immediate auditory feedback is presented when the user performs an action and it is the process of children becoming familiar with this relationship and how to apply it to a group music-making session that is relevant and important in this context.

Therefore, I propose that the term ‘sound-makers’ is used as an alternative to the term ‘musical instruments’. The term ‘musical instruments’ could be inappropriate as it may suggest specific pieces of equipment that: (a) have a standardised method of operation that requires specialist knowledge and skill to play; (b) that have a particular musical application that must be adhered to in group situations; (c) that are expensive to buy and maintain; (d) that are fragile and should not be used by non-expert performers; for example.[5]

When developing the music group for children it was decided that we would create (including the children, where possible/appropriate) a range of ‘sound-makers’ by recycling discarded materials in order to avoid the financial implications of having to buy and maintain traditional ‘musical-instruments’. Additionally, we did not have to consider the way in which they were played (i.e. techniques). One set of ‘sound-makers’ constructed for the children’s group was drums created from round moulded plastic containers of various sizes. These drums were intended to be held between the knees with the base up and struck with the hands. When played in this

[5] The financial implications of acquiring musical instruments or the perceived need for musical training may be prohibitive in group situations. ‘Sound-makers’, as an alternative to traditional musical instruments, are not expensive or elaborate and do not require specialist training in order to play them. The exploration of the relationship between physical actions and resultant sound is a primary reason for many activities involving ‘sound makers’.

way these home-made drums made a very loud resonant sound, the pitch of which differed depending on the size of the container; obviously, the larger the container, the lower the pitch of the sound. We found that some of the smallest containers were less resonant than the larger ones when struck with the hands so decided to experiment with using various forms of beaters in order to create a more satisfying sound. It was found that hard wooden beaters created the most vibrant sound so we created a number of beaters of this nature by using wooden beads and inserting lengths of doweling. Again, this was inexpensive and very easy to construct but allowed for different sounds to be made from recycled plastic containers.

As these plastic containers were originally food packaging, we removed their labels meaning that they were quite unattractive grey or white plastic. During the music group we gave each child a strip of paper and crayons and asked them to draw on the paper and told them that their drawings would be used to decorate the drums. For the remainder of the course, the drum that they decorated was *their* drum, which meant that they felt a sense of ownership and were drawn to the 'sound-maker', thus making them more interested in using it during the music activities. Also, the children were allowed to keep their drum at the end of the group to encourage them to continue to play and experiment with sound, music and rhythm at home.

Another set of 'sound-makers' that we used for the children's groups were shakers, again constructed from various recycled or inexpensive materials. One shaker was made from a small empty plastic container such as those containing vitamin supplements and was filled with a small amount of dried grain such as barley or rice and the cap was fixed with glue to prevent it being opened and the contents lost or swallowed by a child, for example. Again, this was decorated with bright colours, in order for it to appear more attractive to the children. As second type of shaker was made from two tin-cans secured together with some dried grain inside, then covered with paper mch and decorated with brightly coloured paint. Due to the different materials used for the various types of shaker (metal and plastic), each produced a very different sound when played. This meant that the group could experiment with different sounds and could find different applications for the 'sound-makers' based on their distinct timbres, something which encourages them to concentrate on the actual quality of sounds and to focus on elements of music and sound that are less obvious than rhythm or pitch for example. The children found it fascinating that instruments that look similar and are operated in a similar manner can produce such different sounds.

I believe that an important part of musical experience for children, in particular, is to have the opportunity to participate in music making. Neither the musical abilities (or perceived lack of such skills) of family and professionals, or financial constraints of rehabilitation programs should be a barrier to this. As outlined above, the idea of using home made 'sound-makers' rather than 'traditional' musical instruments is a simple, cost effective way to incorporate sound and music (particularly rhythmic elements) into music groups for children or for individual play. With regard to our primary objective for the group, i.e. *fun*, it was obvious (by observing their actions their comments) that the participants enjoyed the groups and had a great deal of fun when they were there. Additionally, a number of the childrens' parents commented that they had never seen their child enjoy music as much as this or to get involved so much and many people told us that their children continued these games and activities at home after each session with family or friends, for example. This was very encouraging and interesting to learn and it also gave us an indication that many of the children derived a positive (and potentially enduring) musical experience as a result of their involvement with the groups.

## 2.6 Conclusions

The practice of getting groups of people together and communicating about music in an environment in which they feel secure and confident provides a unique opportunity for researchers to question, observe and, in some cases, assess the way in which people engage with and relate to music. Additionally, in my experience, the group experience means that each participant is aware that they are discussing such issues with other people in a similar position to themselves and therefore, may feel more comfortable. In the case of each of the music groups outlined above, this environment was particularly interesting as it served to illustrate the similarities amongst the group's reactions to music but, perhaps more interestingly, the *differences* amongst the individuals in the group. This is also the case when considering information gained from conversations with CIUs and their family or friends, for example.

My experiences during this period informed me of a number of important issues regarding CIUs and the way that they engage and interact with music. These experiences greatly influenced my understanding of the area of CIs and music and have resonances throughout the rest of this thesis. The most important thing that I learned was that, although there are a number of similarities between CIUs with regard to the way in which certain elements of music are perceived, understood and enjoyed, it is extremely important to remember, when researching in this area, that we are dealing with *individuals*. Although this seems obvious, I believe that this is even more important to remember when talking about CIUs as the degree of interpersonal variability (with regard to music listening) is perhaps even more wide and unpredictable than in normally hearing people, for example, due to the wide range of personal and technological variables, as outlined in chapter 1.

Therefore, this chapter has outlined the activities that I took part in or helped to organise/run during my internship at the HRF, including devising and running, a music focus group for adults and a four-day music group for children. In outlining these areas, this chapter also presents information regarding the strategies and ideas that were developed for running such groups and the reactions of the participants. An extremely important outcome, and one that has greatly influenced my thinking and the rest of the work in this thesis, can be taken from this work; more specifically, although there are obvious issues affecting the way that CIUs perceive music (see chapter 1, for a more detailed outline), and that such issues often have a negative impact on access to the music signal, many people report that they have had *positive* experience of implant-mediated music listening. Therefore, it seems clear that the musical experience of CIUs should be considered as a complex issue that is not simply reducible to the sound of the music or specific elements of the music.

Chapter 1 presented an outline of a wide range of research in the area of CIs and music which relates mainly to the nature and efficacy of music *perception* with little consideration for the experience of music. The current chapter, however, has outlined a number of 'real-world' investigations into the way in which CIUs relate to and engage with music which highlight, amongst other issues, that positive experiences can be derived from music despite potentially poor access to some elements of the acoustic signal. Musical experience encompasses more than just the assessment of the sound of the 'structural' elements of the music. In relation to this, the following chapter (chapter 3) details a questionnaire study that was conducted as an investigation into the musical experiences of CIUs in Scotland in reaction to previous studies in this area which tend to focus mainly on music perception.

# Chapter 3

# Musical Experiences Questionnaire (MEQ) Study

## 3.1 Introduction

There is a growing body of academic research relating to music listening and cochlear implants, however, such research often focuses mainly on accuracy of CI-mediated music perception (see chapter 1). This research is extremely valuable and may be instrumental in future developments in implant technology or specialised music processing strategies, for example. The current research moves away from focussing primarily on music perception and considers musical experience with the view of gaining information that will contribute to the improvement of such experiences and increase the musical enjoyment of CIUs. Consequently, it was deemed necessary for a study that focussed directly on firsthand accounts of the musical experiences of CIUs within the context of everyday listening situations, i.e. not laboratories.

A self-administered questionnaire study was deemed to be the most effective method for probing the issues discussed in this research due to the geographical dispersal of CIUs in Scotland. There are 800 CIUs in Scotland, 520 of which are adults (over the age of 16 years old) who are widely dispersed from the most northernly in the Shetland Isles and most southernly in Dumfriesshire, all of which are served by the sole NHS cochlear implant programme at Crosshouse Hospital (near Kilmarnock) in the west of Scotland. This would have made face-to-face interviews impractical, time-intensive and costly due to the travel involved. Other advantages of this study being executed using a self-administered questionnaire include: (a) questionnaire studies are more time efficient as they can be sent, either electronically or via the post, to many people at once; (b) participants can take time to consider the answers and complete the questionnaire at their leisure; (c) depending on the speech perception abilities of the CIU, aural communication may be difficult.

The main disadvantage of this method is the inability to be absolutely certain that those who received the questionnaire are the ones completing it, however, this method was more convenient, efficient and cost effective than face-to-face interviews for collecting the particular kind of information sought in this study.

The questionnaire designed for this study was based on one used by Geoff Plant in his work with CIUs at the HRF (Plant, 2004). For the purposes of this study, Plant's questionnaire was expanded upon to include a number of other questions relating specifically to the participant's experience of music, i.e. not only their music perception abilities. The expanded questionnaire also comprised more specific questions relating to the experience of music, other everyday sounds and the respondents' personal details/history of deafness and implantation. The result of this development process was the Musical Experiences Questionnaire (MEQ), which was intended to be the first step in an investigation into the musical experiences of CIUs in Scotland. The MEQ took the form of a forty-seven-point questionnaire with five main sections (see appendix B), as follows:

(a) Personal Details:

This section (Qs. 1 – 14), was designed to collect personal information that would provide insight into the location and demographic of the sample. Participants were also questioned about the types of implants and (if applicable) hearing aids used and duration of use.

(b) Speech Perception:

Questions within this section (Qs. 15 – 23) assed the general level of speech perception of the participants. As there is often variation in the level of successful speech perception in CIUs, this section was used to create a frame of reference for assessing the responses to subsequent sections regarding music, however, no direct analyses comparing the speech perception abilities of the participants and their music listening due to natural variability within the CI population.

(c) Music Listening:

This section (Qs. 24 – 32) was the main focus of the study and was designed to probe the listening experiences of the participants on a pre- and post-implantation basis. The aim was to gain an understanding of: (a) the musical experiences of the participants, and (b) if/how this had changed since receiving the implant. Participants were also given the opportunity to write freely about how these experiences had changed, if at all.

(d) Music Performance (Including Singing):

The questions (Qs. 33 – 46) in this section asked about the participative musical experiences of the respondents in a pre- and post-implantation context, i.e. whether or not implantation has had an effect on their playing of instruments and practical involvement in music/musical activities. Questions relating to singing were included to discern whether singing, a signal that (on a basic level) could be described as tantamount to 'musical (sung) speech', was perceived more or less successfully by CIUs. Put simply, does the fact that singing contains more pronounced melodic and rhythmic cues than speech affect the perception of lyrics and words as opposed to normal speech?

(e) Free Response Opportunity:

The final element of the questionnaire provided space for participants to write freely about their thoughts and feelings about music since receiving their implant in order to gain some further qualitative information. Complete results from this section are presented in appendix C.

Based on current knowledge of the music perception of CIUs gained from the existing body of research it was possible to make hypotheses for some elements of the current study. More specifically, it was hypothesised that:

(a) Results would show a general decrease in the frequency of elective music listening amongst the participants, post-implantation.

(b) Those participants with the most recent and accurate memory of NH music listening would show the greatest decrease in elective music listening frequency, post-implantation.[1]

(c) Results would show that the beat/rhythmic elements of music would be most successfully perceived, post-implantation. This was based on knowledge of the technical strengths of the implant system's processor (see chapter 1) and anecdotal evidence relating to the perception of the rhythmic elements of music by CIUs.

(d) Participants would name and give more positive appraisals of musical instruments that produce a percussive sound.

(e) Results would show a decrease in the number of participants who played a musical instrument post-implantation.

An additional point of interest in this questionnaire was to investigate whether the implanted ear (i.e. left, right or both) of the participant had an effect on the perception and experience of music. Focus on this area was based on research (Zatorre et al., 2002, for example) suggesting that the auditory cortices in each of the hemispheres of the brain are specialised in function so that cortical areas in the left hemisphere have greater temporal resolution, and that spectral resolution is better in the cortical areas of the right hemisphere.

## 3.2 Method

### 3.2.1 Participants

Participants were 69 adult cochlear implant users from Scotland aged between 16-84 years (M = 51.6 years, SD = 15.6) and are all current outpatients of the Scottish Cochlear Implant Program of Crosshouse Hospital in Ayreshire. This sample comprises 25 males (36.2%) and 44 females (64.8%).

### 3.2.2 Procedure

Participants were sent a 47-point questionnaire by post along with an instruction letter explaining the purpose of the study and the available methods for

[1] This does not *necessarily* mean the most recently implanted participants.

completion; namely, the enclosed hard copy or an online method. This letter also provided participants with a unique, randomly generated username that was required to complete both the online and the paper version of this questionnaire. The decision to implement unique usernames in this study was made for two reasons: (1) in order to ensure that participants would only submit one response and, (2) so that only those who received a username would be able to complete the form. As the option was available to complete the form online it was important, so that the data was not contaminated by non-implant users, that the form could not be simply filled out by anyone who came across the page online.

A letter from the Consultant Clinical Physicist of the Scottish Cochlear Implant Programme which explained and endorsed the study was also sent to each participant along with a separate Future Research form which patients could choose to complete, thus providing their contact details so that they could be informed of opportunities to be involved in future research.

As mentioned above, this study was conducted in order to gain an understanding of the general music listening activities of CI users in Scotland. Rather than focusing on a specific element of music perception, this questionnaire was designed to investigate the way in which CIUs engage with music in real life situations and how their perception of music compares to the way in which they perceive speech and other everyday sounds. Where possible, questions were asked in a pre/post-implantation manner so that current perceptions of sound (including music) could be compared to the way sounds were perceived before receiving the implant.

An outline of the questions asked in the questionnaire are presented below; appendix B is a full copy of the actual questionnaire used in this study):

**1.** First half of post-code (eg. EH11, G15 etc.): **2.** Please enter the PASSWORD printed on your information letter: **3.** Gender (circle as appropriate): **4.** What age are you? **5.** What type of cochlear implant do you use? **6.** Do you know the model? **6(b).** Do you know what processing strategy your implant system uses? **7.** Which ear is implanted? **8.** Are you left or right handed? **9.** Where were you implanted? **10.** Do you wear a hearing aid in the other (non-implanted) ear? **11.** How old were you when you became deaf? **12.** Did you use hearing aid(s) before receiving your cochlear implant? **13.** If yes, how old were you when you started wearing hearing aid(s)? **14.** How old were you when you received your cochlear implant?

**15.** How much speech can you understand with your cochlear implant? (1 = None, 2 = Very Little, 3 = A little, 4 = About half, 5 = A lot, 6 = Almost all, 7 = Everything)

**16.** Do you notice any difference in the way that speech sounds since receiving your implant?

**17.** If yes, what do you find different about speech since receiving your implant? **(i)** The words sound: (1 = Clearer to me now, 2 = Less clear to me now, 3 = Just the same) **(ii)** The speakers voice sounds: (1 = Clearer to me now, 2 = Less clear to me now, 3 = Just the same) **(iii)** The meaning of the words are: (1 = Clearer to me now, 2 = Less clear to me now, 3 = Just the same)

**18.** Which of the following best describes the sound of mens and womens voices through your implant? (1 = Mens voices sound much better, 2 = Mens voices sound better, 3 = Mens voices sound a little better, 4 = Mens and womens voices sound about the same, 5 = Womens voices sound a little better, 6 = Womens voices sound better, 7 = Womens voices sound much better)

**19.** Which of the following best describes the sound of mens and childrens voices through your implant? (1 = Mens voices sound much better, 2 = Mens voices sound better, 3 = Mens voices sound a little better, 4 = Mens and children's voices sound about the same, 5 = Childrens voices sound a little better, 6 = Children's voices sound better, 7 = Children's voices sound much better)

**20.** Which of the following best describes the sound of womens and childrens voices through your implant? (1 = Womens voices sound much better, 2 = Womens voices sound better, 3 = Womens voices sound a little better, 4 = Womens and children's voices sound about the same, 5 = Childrens voices sound a little better, 6 = Children's voices sound better, 7 = Children's voices sound much better)

**21.** Since receiving your implant, do you find it harder to understand speech when there is background noise (noisy conditions)? **22.** Are there any situations where you seem to have a lot of trouble understanding speech? If there are please describe them: **23.** If you are talking on the telephone, how much can you understand of what the other person is saying? (1 = None, 2 = Very Little, 3 = A little, 4 = About half, 5 = A lot, 6 = Almost all, 7 = Everything)

**24.** How often did you choose to listen to music before you became deaf? (Tick one box as appropriate) (1 = Never, 2 = Very rarely (once a month), 3 = Rarely (once a week), 4 = Sometimes (more than once a week), 5 = Quite frequently (less than once a day), 6 = Frequently (once a day), 7 = Very frequently (more than once a day))

**25.** What types of music did you enjoy listening to before becoming deaf? (Folk, Rock, Reggae, Country, Opera, Rap/Hip Hop, Classical, Pop (since 1960), Pop (before 1960), Jazz, Easy Listening, World, Blues, Musicals, Solo Instrumental, Electro, Other.) **25(b).** If other, please tell us about it. Also, feel free to add any other information that may be appropriate:

**26.** How often do you choose to listen to music since receiving your implant? (Tick one box as appropriate) (1 = Never, 2 = Very rarely (once a month), 3 = Rarely (once a week), 4 = Sometimes (more than once a week), 5 = Quite frequently (less than once a day), 6 = Frequently (once a day), 7 = Very frequently (more than once a day))

**27.** What types of music do you enjoy listening to since receiving your implant? (Tick as appropriate) (Folk, Rock, Reggae, Country, Opera, Rap/Hip Hop, Classical, Pop (since 1960), Pop (before 1960), Jazz, Easy Listening, World, Blues, Musicals, Solo Instrumental, Electro, Other.) **27(b).** If other, please tell us about it. Also, feel free to add any other information that may be appropriate:

**27(c).** If your music listening habits have changed since being implanted, would you say that this is due to the fact that you now use a cochlear implant?

**28.** Do you notice any difference in the way that music sounds since receiving your implant? (circle as appropriate)

**29.** If yes, what do you find different about the music since receiving your implant? (tick one box from each column)

**(i)** The tune/melody sounds: (1 = Clearer to me now, 2 = Less clear to me now, 3 = Just the same) **(ii)** The instruments sound: (1 = Clearer to me now, 2 = Less clear to me now, 3 = Just the same) **(iii)** The beat/rhythms sound: (1 = Clearer to me now, 2 = Less clear to me now, 3 = Just the same)

**29 (b).** Please give details about your answers:

**30.** Are there some instruments that sound particularly good through your implant? If so, why? Please give details: **31.** Are there some instruments that sound particularly bad through your implant? If so, why? Please give details:

**32.** Which is more important to you; music or speech? (1 = Music much less important, 2 = Music less important, 3 = Music a bit less important, 4 = Both equally important, 5 = Music a bit more important, 6 = Music more important, 7 = Music much more important)

**33.** Did you play a musical instrument before becoming deaf/receiving your implant? **34.** If yes, what instrument(s) did you play? **35.** Did you have music lessons before becoming deaf/receiving your implant? **36.** If yes, please give details: **37.** Did you play this instrument in a group or an ensemble etc.? **38.** If yes, please give details: **39.** Do you play this (or any instrument) since receiving your implant? **40.** If yes, please give details: **41.** If you had music lessons on your instrument prior to receiving your implant, have you continued with these lessons? **42.** Please give details if appropriate: **43.** If you still play an instrument, since receiving your implant, do you play it in a group or ensemble etc.? **44.** Please give details if appropriate:

**45.** Did you enjoy singing more before or since receiving your implant? (1 = Much better before, 2 = Better before, 3 = Mostly better before, 4 = No difference , 5 = Mostly better now, 6 = Better now, 7 = Much better now)

**46.** From your perspective, has the sound of your singing voice changed since receiving your implant? Please give details:

**47**. We would really appreciate any other information you have about music through your cochlear implant. Please use the space below to tell us anything that you feel relevant including your thoughts and feeling about music since receiving your implant:

## 3.3 Results

Results presented below are presented in subsections based on the structure of the questionnaire for ease of comprehension and consideration, due to the large quantity of data to be presented in this chapter.

### 3.3.1 Participant Details

The period of time in which participants had been using a cochlear Implant varied from 4 months - 17 years (M = 6.7 years, SD = 4.6) and the period of pre-implantation deafness varied from 6 months – 42.5 years (M = 25.6 years, SD = 16.5). 63 (91.3%) of the participants wore hearing aids prior to receiving their cochlear implant, 4 of which have continued to wear a hearing aid in the non-implanted ear. The period of pre-implantation use of hearing aids ranged from 1-64 years (M = 25.7, SD = 15.3). 6 (8.7%) of the participants did not use hearing aids prior to receiving their implant and do not use hearing aids in the non-implanted ear.

The manufacturers represented by this study were Advanced Bionics (n = 5; models included Auria and Clarion Platinum), Cochlear (n = 58; models included Neucleus 22, Neucleus 24, Neucleus Freedom, Esprit 3G and Harmony) and MED-EL (n = 6; models included Opus).

The sample comprised of 41 people (59.4%) with left-ear implants, 28 people (40.6%) with right-ear implants and no participants with bilateral implants. 8 of the participants (11.6%) were left-handed and 61 (88.4%) were right-handed. Table 3.1 (below) displays the relationship between the implanted ear and the handedness of the participants.

| | Left Ear Implant | Right Ear Implant | Total |
|---|---|---|---|
| Left Handed | 5 | 3 | 8 |
| Right Handed | 36 | 25 | 61 |
| Total | 41 | 28 | 69 |

Table 3.1: Implanted ear/handedness

### 3.3.2 Speech Perception

As is illustrated by table 3.2 (below), 95.7% of the sample report that they are able to understand at least half of speech they hear via their implants. 87% of the sample report their perception of speech is clearer since receiving their implant.

75.4% of the sample, when questioned about the perception of speech, believe that the clarity of the words and the clarity of the speaker's voice has improved since

| Everything | Almost All | A Lot | About Half | A Little | Very Little | None |
|---|---|---|---|---|---|---|
| 8.7% | 37.86% | 30.43% | 18.84% | 1.45% | 1.45% | 1.45% |

Table 3.2: Amount of Speech Perception with Cochlear Implant

receiving their implant. 60.9% report that the meaning of the words has improved, post-implantation (as shown in table 3.3, below).

| | Clearer Now | Less Clear Now | Just the Same |
|---|---|---|---|
| Clarity of Speaker‘s Voice | 75.36% | 10.5% | 14.49% |
| Meaning of Words | 60.86% | 10.5% | 28.99% |

Table 3.3: Changes in the Perception of Speech

Results from questions relating to the comparative sound of men's, women's and children's voices are presented in the following three graphs which show that 36.2% of people believe that the sound of men's voices, via the implant, is at least a little better than women's voices. 23.2% believe that the sound of women's voices is at least a little better than that of men's voices (see figure 3.1).

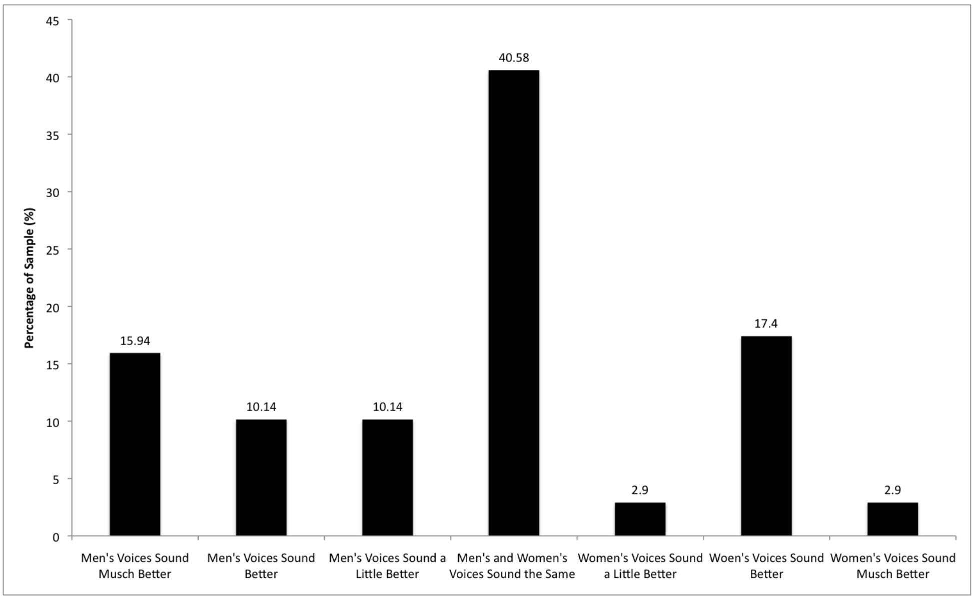



Figure 3.1: Comparison of the Sound of Men's and Women's Voices

43.4% of respondents report that, via the implant, men's voices sound at least a little better than children's voices. 24.6% report that children's voices sound at least a little better than men's voices. (see figure 3.2).

52.2% of the sample, when questioned about the sound of women's voices

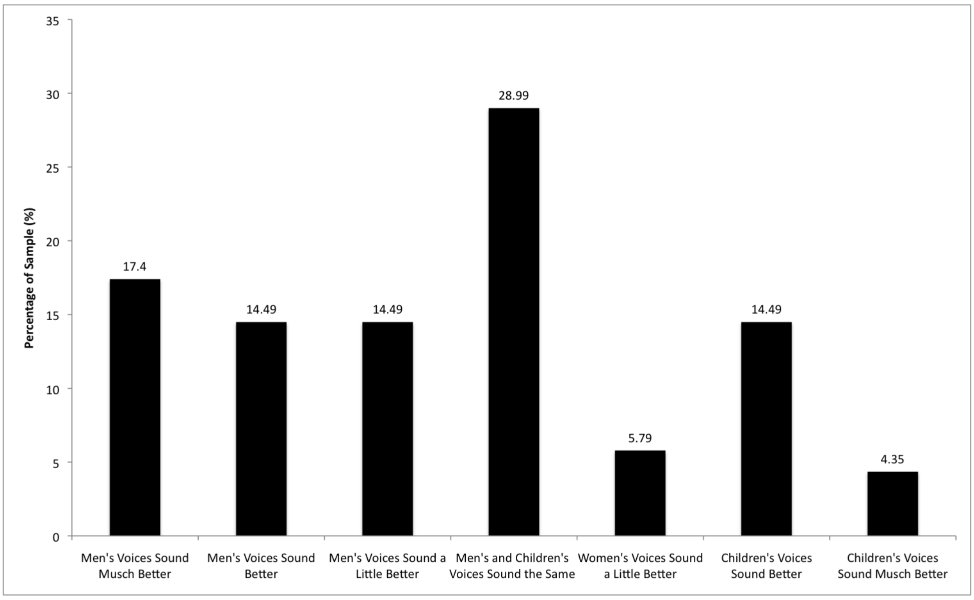



Figure 3.2: Comparison of the Sound of Men's and Children's Voices

compared with children's through their implant, report that women's voices sound at least a little better than children's voices. 13% of the sample report that the sound of children's voices are at least a little better than women's through the implant (see figure 3.3).

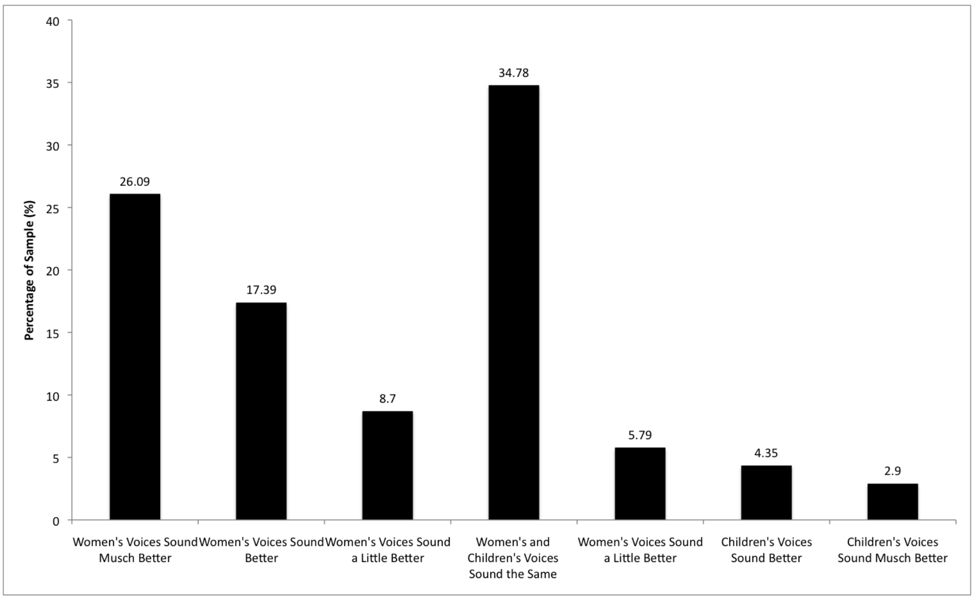



Figure 3.3: Comparison of the Sound of Women's and Children's Voices

With regard to the effects of ambient noise on speech perception, 69.6% of the participants reported that, since receiving their implant, it is more difficult to understand speech when there is background noise. Table 3.4 (below) outlines some of the reasons for diminished speech perception in conditions of background noise that were offered by those respondents who noted increased difficulty since implantation. Responses have been categorised and condensed, based on common themes and subject areas, for ease of consideration.

| Category | Condensed Responses |
|---|---|
| Lack of Visual Cues | Trouble understanding speech without visual cues (e.g. when peoples lips can't be seen to lip-read).<br>When In dark rooms or outdoors at night.<br>It is difficult to understand people who wear dark sunglasses. |
| Social Settings | Some participants lose track of conversations when in groups of people (more than one-to-one).<br>It can be difficult to understand people in bars or restaurants.<br>People who mumble are difficult to understand.<br>People who talk too quickly or with their mouths full are difficult to understand.<br>It is difficult to understand people with foreign accents. |
| Technology | Difficulties talking on the telephone.<br>Difficulties using hearing loop whilst driving or listening to the radio/TV. |
| Outdoors | Ambient outdoor noise can make speech perception difficult (wind in trees etc).<br>Traffic Noise.<br>Background noise in shops and shopping centres can make it difficult to understand speech. |

Table 3.4: Reasons for diminished post-implantation speech perception

56.5% of the sample reported that they are able to understand at least half of what the other person says when speaking on the telephone (see table 3.5, below).

| Everything | Almost All | A Lot | About Half | A Little | Very Little | None |
|---|---|---|---|---|---|---|
| 1.45% | 27.54% | 17.39% | 10.14% | 14.45% | 8.7% | 20.29% |

Table 3.5: Speech Comprehension via the Telephone

### 3.3.3 Music Listening

Participants were questioned on the frequency of their elective music listening on a pre- and post-implantation basis by means of seven-point Likert scales as shown in figure 3.4:

1 = None
2 = Very Little
3 = A little
4 = About half
5 = A lot
6 = Almost all
7 = Everything

Figure 3.4: Music Listening Frequency Likert-Style Item

The change in frequency was analysed and the results are presented in figure 3.5.[2].

| Group | N | Mode* | | p= | Mean Duration Pre-imp' Deafness (years) | SD (years) | Mean Age (years) | SD (years) |
|---|---|---|---|---|---|---|---|---|
| | | Pre | Post | | | | | |
| Whole Sample | 69 | 7 | 1 | 0.0165 | 25.6 | 16.5 | 51.6 | 15.6 |
| Late-deafened (age ≥ 13) | 39 | 7 | 1 | 0.0003 | 18.7 | 12.7 | 56.9 | 12.5 |
| Pre-adolescent-deafened (age < 13 ex. congenitally deaf participants) | 20 | 7 | 5 | 0.3413 | 38.1 | 15.1 | 50.1 | 14.2 |
| Congenitally deaf | 10 | 1 | 6 | 0.0222 | 27.9 | 18.1 | 33.8 | 16.5 |

Figure 3.5: Grouped Elective Music Listening Frequency. * = Numbers relative to Likert scale items

As can be seen from figures 3.6, 3.7 and 3.8, there is, generally, a decrease in the frequency of which the sample listen to most of the styles/genres listed on the questionnaire.

| Genre/Style listened to by Congenitally Deaf Group | | | |
|---|---|---|---|
| Genre/Style | Pre-imp Listeners | Post-imp Listeners | +/- |
| Rock | 1 | 4 | + |
| Rap/Hip-Hop | 0 | 3 | + |
| Electro | 1 | 3 | + |
| Jazz | 0 | 2 | + |
| Blues | 1 | 2 | + |
| Other* | 0 | 1 | + |
| Easy Listening | 1 | 1 | = |
| World | 0 | 0 | = |
| Pop (before 1960) | 0 | 0 | = |
| Reggae | 1 | 1 | = |
| Pop (since 1960) | 4 | 3 | - |
| Musicals | 2 | 1 | - |
| Solo Instrumental | 1 | 1 | - |
| NONE | 5 | 1 | - |
| Country | 2 | 0 | - |
| Folk | 1 | 0 | - |
| Opera | 1 | 0 | - |
| Classical | 1 | 0 | - |

* Other = 'Anything with a beat'.

Figure 3.6: Genre/style listened to by Congenitally Deaf group (pre/post implantation)

| Genre/Style listened to by PA-Deaf Group | | | |
|---|---|---|---|
| Genre/Style | Pre-imp Listeners | Post-imp Listeners | +/- |
| Country | 5 | 10 | + |
| Pop (before 1960) | 2 | 4 | + |
| Opera | 3 | 5 | + |
| Classical | 3 | 4 | + |
| Pop (since 1960) | 10 | 10 | = |
| Other | 0 | 0 | = |
| Easy Listening | 5 | 5 | = |
| World | 0 | 0 | = |
| Solo Instrumental | 2 | 2 | = |
| Electro | 1 | 1 | = |
| Rap/Hip-Hop | 2 | 1 | - |
| Reggae | 2 | 1 | - |
| Blues | 2 | 1 | - |
| Musicals | 6 | 5 | - |
| Rock | 9 | 8 | - |
| NONE | 5 | 4 | - |
| Jazz | 2 | 1 | - |
| Folk | 4 | 2 | - |

Figure 3.7: Genre/style listened to by Pre-Adolescent Deafened Group (pre/post implantation)

Participants were asked whether they believe that any post-implantation changes they may have experienced in their music listening habits are a result of the fact that they now use a cochlear implant. 82.6% of the participants report that they feel that this was the case.

97.1% of the participants reported that they notice a change in the way that music sounds since receiving their implant. When questioned specifically about whether their perception of certain elements of music (tune/melody, beat/rhythm and instrumental sounds) were clearer/less clear since receiving their implants the

[2]numbers relative to the Likert scale shown in figure 3.4

| Genre/Style listened to by Late-Deaf Group | | | |
|---|---|---|---|
| Genre/Style | Pre-imp Listeners | Post-imp Listeners | +/- |
| NONE | 5 | 15 | + |
| Other | 4* | 4† | = |
| Musicals | 27 | 10 | - |
| Classical | 23 | 8 | - |
| Pop (since 1960) | 26 | 14 | - |
| Easy Listening | 25 | 13 | - |
| Country | 23 | 13 | - |
| Folk | 18 | 8 | - |
| Rock | 12 | 6 | - |
| Blues | 10 | 4 | - |
| Pop (before 1960) | 13 | 5 | - |
| Solo Instrumental | 12 | 5 | - |
| Jazz | 10 | 4 | - |
| Opera | 7 | 3 | - |
| World | 5 | 1 | - |
| Reggae | 5 | 3 | - |
| Rap/Hip-Hop | 3 | 0 | - |
| Electro | 2 | 0 | - |

* Other (pre-implantation) = 'Choral music', 'Accordion music'
† Other (post-implantation) = 'Pipe-bands' (multiple reports), 'Anything with a beat', 'Rhythmic Music'

Figure 3.8: Genre/style listened to by Late Deafened Group (pre/post implantation)

sample reported the following. Results are presented in three groups relating to the nature of the participants' deafness, i.e. late-deafened, pre-adolescent-deafened and congenitally deaf.

| | Clearer Now | Less Clear Now | Just the Same |
|---|---|---|---|
| Tune/Melody | 14 | 21 | 4 |
| Instrumental Sounds | 13 | 20 | 6 |
| Beat/Rhythm | 15 | 15 | 10 |

Table 3.6: Changes in the Perception of Musical Elements for the LD Group

| | Clearer Now | Less Clear Now | Just the Same |
|---|---|---|---|
| Tune/Melody | 12 | 5 | 3 |
| Instrumental Sounds | 12 | 2 | 6 |
| Beat/Rhythm | 13 | 2 | 5 |

Table 3.7: Changes in the Perception of Musical Elements for the PAD Group

| | Clearer Now | Less Clear Now | Just the Same |
|---|---|---|---|
| Tune/Melody | 7 | 1 | 2 |
| Instrumental Sounds | 7 | 2 | 1 |
| Beat/Rhythm | 8 | 0 | 2 |

Table 3.8: Changes in the Perception of Musical Elements for the CD Group

Table 3.6 shows that the majority of the LD group report that the tune/melody and instrumental sounds are less clear post-implantation and that the majority believe that the beat/rhythmic elements of music are clearer now or the same as before. Tables 3.7 and 3.8 show that the majority of each group believe that each musical element that they were questioned about is clearer, post-implantation.

Based on neurological research relating to functional asymmetries in the auditory cortex, this data was further analysed with regard to which ear was implanted. Only those participants who described themselves as right handed were included in this analysis due to uncertainties relating to left-handedness and hemispheric dominance.

As can be seen from tables 3.9 and 3.10 the changes in post-implantation music perception of right-handed CI users with right ear implants (RH/RI) and those with left ear implants (RH/LI) are different. With regard to the perception of melodic elements of music, the clarity of the instruments and the clarity of any words/vocals, it would appear that, in general, RH/LI users notice more of a difference than RH/RI users since receiving their implant.

| | Clearer Now | Less Clear Now | Just the Same |
|---|---|---|---|
| Tune/Melody | 32% | 52% | 16% |
| Instrumental Sounds | 44% | 36% | 20% |
| Beat/Rhythm | 36% | 28% | 36% |

Table 3.9: RH/RI perceptions of changes in post-implantation music listening

| | Clearer Now | Less Clear Now | Just the Same |
|---|---|---|---|
| Tune/Melody | 44% | 36% | 20% |
| Instrumental Sounds | 39% | 36% | 25% |
| Beat/Rhythm | 44% | 25% | 31% |

Table 3.10: RH/LI perceptions of changes in post-implantation music listening

Figure 3.9 and figure 3.10 show only those participants who stated that they noticed a difference in the post implantation perception of music. The majority of RH/RI users report that the tune and melody of the music is less clear since receiving their implant but state that the sounds of the instruments and the sound of the beat and rhythms are clearer now.

In figures 3.9 and 3.10, for both tune/melody and instrument sounds, we notice that the majority the groups show opposite results. That is to say that for RH/RI

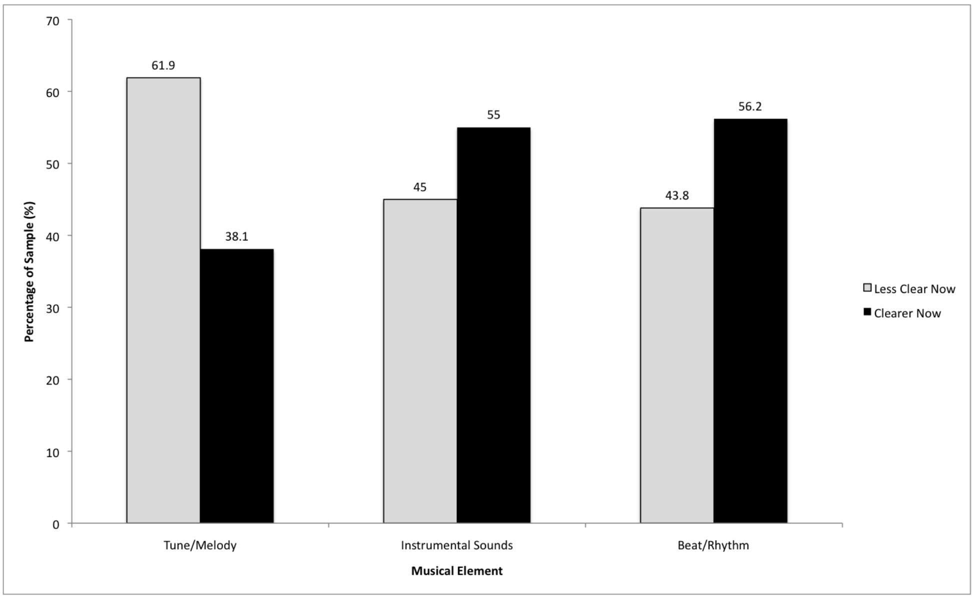



Figure 3.9: RH/RI perceptions of changes for participants who report a change

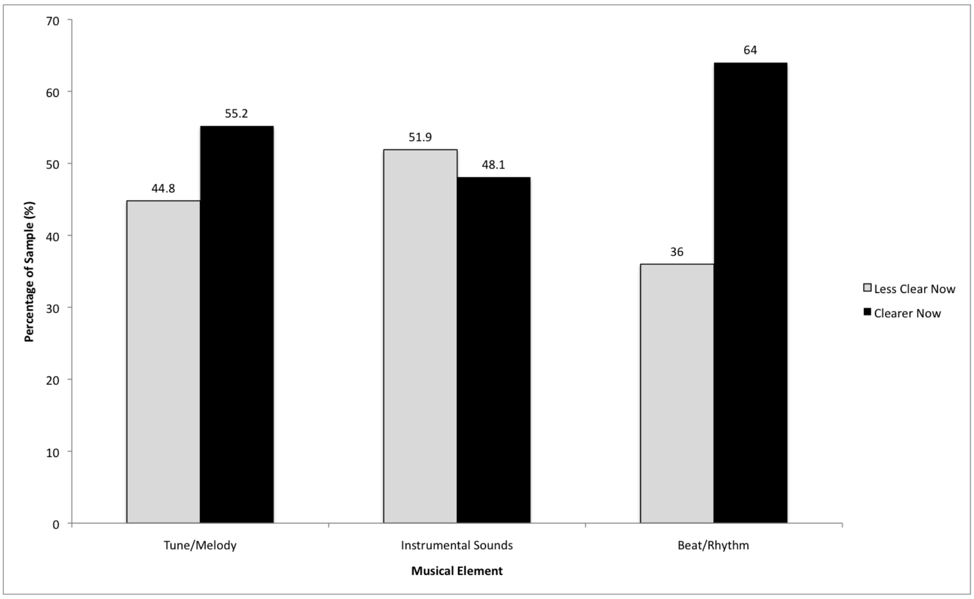



Figure 3.10: RH/LI perceptions of changes for participants who report a change

participants, the majority of the group report that the tune/melody is less clear, the majority of the RH/LI group report the opposite. Similarly with the instrumental sounds, the majority of the RH/RI group report that this element is clearer, post-implantation; the RH/LI group again, report the opposite. However, for each of these musical elements, the majority is greater in the case of the RH/RI participants. With regard to the beat/rhythmic elements of music, however, the majority of each group report that this is now clearer, since receiving their implant. Comparisons between RI and LI users are not statistically significant (see table 3.11).

| | |
|---|---|
| Tune/Melody | p = 0.63 |
| Instrumental Sounds | p = 0.53 |
| Beat/rhythms | p = 0.54 |

Table 3.11: Comparison of RH/LI and RH/RI Groups for Musical Elements[3]

Table 3.12 (below), shows the instruments that participants feel sound either particularly good or particularly bad through their implant. Those instruments that are underlined and italicised has been reported, by different participants, as sounding particularly good and bad.

| Instruments reported as sounding good | Instruments reported as sounding bad |
|---|---|
| Drums, bass guitar, piano, bagpipes, low end of the piano, percussion, saxophone, violin, harp, cello, tympani, guitar. | High pitched woodwind instruments, bagpipes, piano, guitar, violin, electronic instruments, organ at church (painful), flute, whistles, xylophone, all musical instruments. |

Table 3.12: Reports of 'Good'/'Bad' Sounding Instruments

As is shown by table 3.13, only 1.45% of the sample reports that the perception of music is more important than speech and 34.88% report that music and speech perception are equally important. The majority of the sample (62.79%) report that music perception is at least a bit less important than speech perception.

| | |
|---|---|
| Music Much Less Important | 20.29% |
| Music Less Important | 23.19% |
| Music a bit Less Important | 11.59% |
| Music Equally Important | 43.48% |
| Music a bit More Important | 0% |
| Music More Important | 0% |
| Music Much More Important | 1.45% |

Table 3.13: The relative Importance of Music and Speech Perception

### 3.3.4 Music Performance (Including Singing)

17.4% of participants report having played a musical instrument before becoming deaf/receiving the implant. Instruments played included Piano, Keyboards, Synthesisers, Percussion, Drum-Kit, Guitar, Violin, Flute, Recorder, Accordion, Vocals and Computer-Generated Music. All of those who played a musical instrument before becoming deaf/receiving their implant received music lessons and only two people played in an ensemble settings; specifically, piano in a church choir and flute in a school band.

Since receiving their CIs, only the participant who played piano in a church choir has continued to play their instrument and none of the participants have started to play another musical instrument since implantation.

As can be seen from figure 3.11 below, the majority of the sample (58%) report that they do not notice a difference in their enjoyment of singing since receiving their implants. Of the remainder of the sample, 27.5% state that they preferred singing before implantation and 14.5% prefer singing more since receiving their implant.

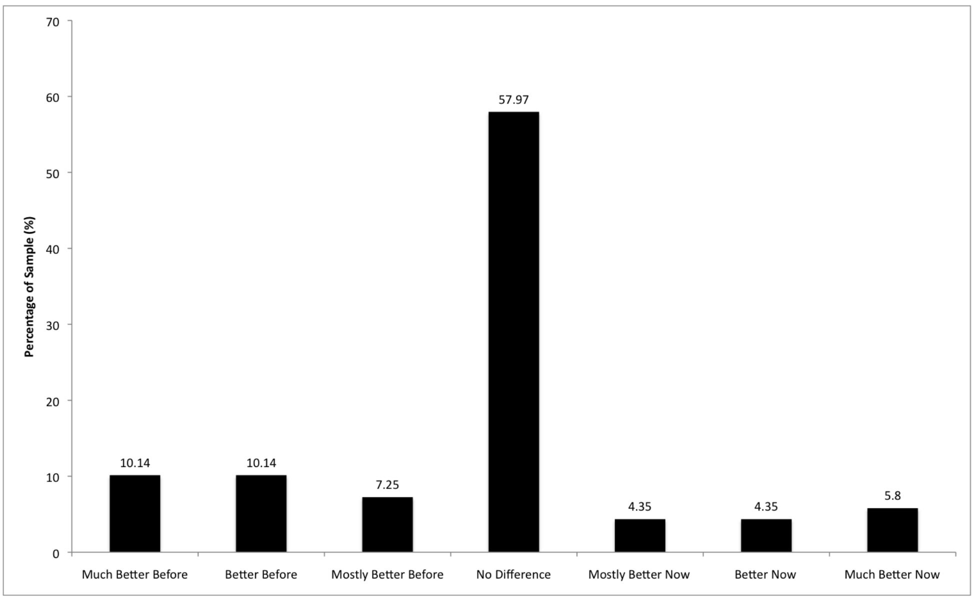



Figure 3.11: Pre/post-Implantation Preference for Singing

### 3.3.5 Free Response Results

A complete transcription of all the answers provided in the last question of the questionnaire (i.e. the free response section) are presented in C. The following is a condensed summary of the results:

| Group | Condensed Responses |
|---|---|
| CD | Words obscured if a lot of instruments playing simultaneously.<br>Lyrics difficult to understand (Except with rap music)<br>I love Music. |
| PAD | Playing music again would be difficult as pitch sounds completely different.<br>Higher frequencies have now returned to their normal volumes.<br>I miss hearing music.<br>Frustrated by the sound of music as distortion makes song recognition difficult.<br>Cannot make out lyrics without written version.<br>Female singing voices are very difficult to hear.<br>Sometimes difficult to make out familiar melodies.<br>Disappointment in the sound of music.<br>Easier to follow live music or music with captions (at theatre).<br>Regret being implanted because of negative impact on music listening.<br>Music is clearer and it's easy to appreciate the sound of different instruments. |
| LD | Disappointment in not 'hearing/understanding' music despite occasionally recognising familiar melodies.<br>Building up *tolerance* to having music on.<br>Feeling 'uninvolved' in social occasions/events/ceremonies (baptisms, carol concerts, nativity plays) prior to implantation but now I enjoy them *emotionally*.<br>Not enjoying music any more, however but hearing beats more than before.<br>Acceptable music listening through direct input of mp3 cable.<br>Modern music is a bit difficult to get to grips with but at least there appears to be a definite rhythm.<br>Music sounds very high pitched and can be very difficult to put up with for long. |

| Group | Condensed Responses |
|---|---|
| | Sometimes the silence is better than the sound [*of music*]. |
| | Beat/rhythm easy to perceive but not the tune or the sound of the instruments. |
| | Unable to discern words or tunes. |
| | Reliance on memory to make out tunes. |
| | Regardless of the instruments I am unable to recognise tunes. |
| | Music does not sound like it did pre-deafness. |
| | Music requires perseverance and effort to make it sound normal. |
| | Unable to socialise the same way due to missing music. |
| | Easier to understand on TV rather than a hi-fi. |
| | Music sounds like noise . |
| | Vocals obstructed by other instruments - particularly at high volumes. |
| | Music is an important part of life. |
| | Able to make out songs from musicals at the theatre. |

Condensed Summary of Free Response Results

## 3.4 Discussion

### 3.4.1 Speech Perception

In general, the speech perception ability of the group was very high with the vast majority of the sample reporting that they are able to understand at least half of the speech that they perceive via their implant and a high proportion of the sample (46.4%) reporting that they are able to understand everything or almost everything. In addition, the majority of the sample (56.5%) report that they are able to hear at least half of speech via the telephone; a long-held signifier of successful implant use. Interestingly, however, 20.3% of the sample report that, when speaking on the telephone, they are unable to understand what the other person is saying which shows that there is a degree of variability within this sample.

Questions relating to the relative sound of men's, women's and children's voices were posed to the participants in order to probe whether or not there was a difference in the way that these sounds were perceived. It was expected that the sound of men's voices would be favoured based on the presumption that they are generally lower in pitch than the voices of women and children. Similarly, it was thought that women's voices would be favoured over the voices of children for the same reason.

The results show that a large proportion of the sample believe that men's and women's speaking voices sound as good as each other. Of the rest of the participants, 36.2% believed that men's voices sound at least a little better than the voices of women and only 23.2% believe that women's voices sound better than the voices of men. However, this is somewhat different when comparing the sound of men's voices and children's voices as only 29% of the sample report that the sound of men's and children's voices as being equal. Of the remainder of the sample, the majority (46.4%) report that men's voices sound better than the voices of children and only 24.6% report that children's voices sound better than men's.

These results are consistent with the expectation that the (generally) lower pitched voices of men would be more favourable to CIUs than those of women and Children. I believe that this is more evident in the comparison of men's and children's voices as the differences in the pitches of the voices are perhaps more obvious. Interestingly, however, this distinction is even more pronounced when comparing the results of the comparison of women's and children's voices. 34.8% of the sample believe that the sound of women's and children's voices are of equal quality through their implants. Of the remainder of the sample only 13% favour the sound of children's voices through their implant whereas 52.2% believe that women's voices sound better than the voices of children.

If we continue to use the generalisation of men having lower-pitched voices than women and woman having lower-pitched voices than children, we can begin to understand why this may be the case. If, for example, a man's speaking voice had an average fundamental frequency of 120Hz (Traunmller & Eriksson, 1995, p1), this would mean that the harmonic series of this average fundamental frequency would be (approximately): F0 = 120Hz, F1 = 240Hz, F2 = 360Hz, F3 = 480Hz, and so forth. However, with women, a hypothetical average fundamental frequency of 210Hz (ibid.) shows a harmonic series of F0 = 210Hz, F1 = 420Hz, F2 = 630Hz, F3 = 840Hz. From this we can say that the lower pitched average fundamental frequency of male speaking voices, has greater harmonic structure than that of the higher pitched average fundamental frequency of female speakers. This may mean that the CI system is likely to deal with sounds of lower frequencies more successfully because they potentially have more access to the harmonic information.

With regard to the post-implantation perception of the sound of speech, the vast majority of the sample (87%) feel that this is different to that which they remember from before receiving their implant and most participants report that this is a positive difference. The majority of the sample state that the clarity of the words, the clarity of the speakers voice and ability to understand the meaning of the words have improved since receiving their implant, a result which suggests that the speech perception abilities of this group have improved in general since receiving their implant.

Anecdotal evidence suggests that CIUs experience difficulties with speech perception when in environments with increased background noise, something that was also reported by 69.6% of this sample. Although the majority of the participants report that this is the case, a considerable percentage (30.4%) reported that, since receiving their implant, speech perception is not diminished in environments with ambient noise. Although this is very encouraging, the possible causes of this result are numerous. It may be, simply, that these respondents are particularly successful CIUs whose speech perception performance is so good that the background noise does not detract from or interfere with their communication. It may be that these users are using newer and more advanced CI systems with better processing abilities or microphone settings that allow more directional pick-up patterns or which have better noise attenuation filters. Also, this may due to the fact that the signals perceived by these participants prior to receiving their implant were considerably worse than those that they are receiving now due to congenital deafness or poor hearing aid performance for, example, and thus comparatively, the perception of the signal via the CI is better than any remembered signal. It is also reasonable to suggest that, as a result of their implants and improved hearing, CIUs are also more exposed to noise and are also more likely to notice the effect it has on communication in various situations.

The results from this section suggest that the participants in this study are generally successful implant users who are largely able to perceive speech, communicate on the telephone and generally in quiet environments. Consistent with anecdotal evidence, the majority of this sample have difficulties with speech perception when there is increased ambient noise or when they are in situations where they have limited access to visual cues (e.g. in the dark, when the speaker's face is covered or their lips cannot be seen to lip-read etc.). With regard to the sound of the speaker's voice, results show that the sample have a general preference for adult voices over those of children and that men's voices are favoured slightly more than women's voices. This may be a result of the fact that men's voices are generally lower in pitch than women's voices and that women's voices are generally lower in pitch than those of children. This is also consistent with a great deal of anecdotal evidence suggesting that lower frequencies are often better perceived and, in turn, preferred by CIUs, possibly as a result of greater harmonic structure in sounds of lower fundamental frequencies.

### 3.4.2 Music Listening

Questions relating to the pre/post-implantation, elective music listening habits of the participants provided some interesting information regarding the frequency with which participants choose to listen to music. Generally speaking, the results of this study show that there is a substantial decrease in the frequency of post-implantation music listening and most notably, that there has been an increase of 30% in the number of participants who do not choose to listen to any music since receiving their implant.[4]

Table 3.5 (above) outlines the change between pre-/post-implantation elective music listening frequency relative to the seven-point Likert scale used in the questionnaire (see Figure 3.4, above). The data in this table is consistent with the hypothesis relating to this question; namely that change between the pre-/post-implantation elective music listening frequency would show a general decrease for the sample. Furthermore, the hypothesis was that those participants who have the greatest pre-implantation memory of music from a NH perspective (i.e. the late-deafened group) would show the greatest decrease in elective music listening frequency. Additionally, those participants who are presumed to have less accurate memories of NH music (the pre-adolescence-deafened group, excluding the congenitally deaf), also show a drop in the frequency of elective music listening, although a far smaller decrease than the late-deafened group. This is, again, consistent with the hypothesis as this group are presumed to have a less accurate/reliable memory of NH music listening and will therefore have less to compare implant-mediated listening to, in turn resulting in less avoidance of music listening.

Interestingly, when we consider this change in congenitally deaf participants who will have no memory of NH music listening, we notice an increase in the frequency with

[4]When asking questions about the way in which music is perceived, no distinction was made between live and recorded music. The initial reasons for this were twofold; firstly, in an attempt to avoid any confusion that may arise from asking questions that were too specific, and secondly; as it was felt that this dichotomy may be better and more meaningfully explored practically/experimentally rather than via an investigative self-administered questionnaire.

which they choose to listen to music; again, consistent with the hypothesis. In this case we can postulate, since there is no memory of NH music listening to compare with, that the implant-mediated sound of music is acceptable to these participants. This provides more support for the hypothesis that the evaluation of, and subsequent engagement with, implant-mediated music listening is dependent, to an extent, on the comparison between this and the NH memory of music.

Questions relating to the genre/style of music listened to give results that are difficult to generalise and that are most relevant and interesting when considering individual differences. Having a knowledge of the types of music that participants choose to listen to and being able to compare these on a pre/post-implantation basis is very useful as it may give an insight into the elements of music that participants are hearing most clearly or, the types of music which provide the best musical experience for the individual. As can be expected, based on the finding that the participants are choosing to listen to music less frequently, the results relating to the changes in the styles/genres of music listened to also show a general decrease in the number of people (across the whole sample) who choose to listen to most styles. As was proposed in chapter two, however, the musical experience is not solely related to the sensory experience of musical signal but is also effected by the other issues which could be described to fall into the category of social and cognitive experience.

Table 3.6 shows that the genres/styles that are listened to by more participants, post-implantation, in the congenitally deaf group are Rock, Rap/Hip-Hop, Electro, Jazz, Blues, and 'Other' (quoted as 'Anything with a Beat'). When considering the nature of these forms of music it can be noted that they could be considered styles that are characterised by or associated with strong rhythmic elements. This is particularly interesting when we consider it in conjunction with the responses from participants suggesting that the beat/rhythmic elements of music are clearer since implantation. Also, this is consistent with the considerable amount of anecdotal evidence and academic research suggesting that the beat or rhythmic elements of music are among the best perceived by CIUs.

When considering the typical vocal elements of those styles which are more favoured, post-implantation, it may be reasonable to posit that such vocal styles may be consistent with the research by Cleaveland et al (2001) or Kovai et al (2003), for example, with regard to the similarity in the LTAS of the singing and speaking voices of ‘country singers’ and ‘folk singers’, respectively. This research involved professional singers and showed, in a general sense, that the LTAS of the country/folk singers showed no evidence of the singers formant (i.e. a peak of energy at approximately 2.8kHz) and that, in turn the LTAS of their singing and speaking voices were similar. This was tested in comparison with professional ‘trained’ classical singers who displayed the singers formant in their singing voice but not in their speaking voice. With regard to the current research, it is not unreasonable to postulate that the singing voices of performers in the genres listed above might have comparable spectral similarities with their speaking voices. Therefore, it may be suggested that the vocal elements of these genres may be more easily perceived by CIUs as they could be considered musical speech. Although this is conjecture, at this stage, it may be one of the reasons, along with the strong rhythmic elements, explaining why CIUs are drawn to these styles of music. In addition, we notice that the number of participants in this group who state that they listen to no music since receiving their implant has decreased; a finding which is consistent with the elective music listening frequencies of this group.

Table 3.7, shows that the styles Country and Pop (from before 1960) are those listened to by more people in the pre-adolescent deafened group, post-implantation. Again, Country music and pre-1960 pop (rock’n’roll, skiffle, for example) could be considered as music with strong rhythmic elements and, styles that have typical vocal elements that also fall into the category of musical speech, particularly with regard to country music (see above). In this group, results also show that the number of participants who report that they listen to no music since receiving their implant has decreased, although to a lesser extent than in the previous group.

Table 3.8 shows that, in the late deafened group, the only category in which there is an increase (post-implantation) is those participants who report listening to no music, (three-times as many people). This is also consistent with the finding that participants in this group choose to listen to music less frequently since receiving their implant. Additionally, participants who elected to note other styles of music, state that prior to implantation, they chose to listen to such styles of music as choral music and accordion music. However, those who report listening to other styles subsequent to implantation give distinctly different alternatives, namely, pipe bands (which were frequently reported) and other participants suggest ‘anything with a beat’ and simply ‘rhythmic music’.

This is also a very interesting finding and as it provides yet more explicit evidence suggesting that the beat/rhythmic elements of music are favoured by CIUs and that one of the only criteria that some CIUs in this group have when choosing to listen to music is the presence of strong or distinct rhythm or a prominent beat. Pipe band music was also frequently reported as a style that many CIUs in this group choose to listen to. On face value we can analyse this choice and rationalise it by considering that music of this style usually has a very strong rhythmic element as a result of the multiple drums involved in pipe bands and the various levels of rhythmic structures present in the music. In addition, by their very nature pipe bands also have a strong and constant pitched drone that accompanies the melodic information. As this is not a complex form of harmony per se but, rather, a stable and constant harmonic reference this may also be appealing to CIUs. Additionally, it must be noted that this questionnaire was administered to CIUs living in Scotland and that the proclivity for pipe band music may be due to the cultural aspects of this music and it's strong association with Scotland and national patriotism. If there is an element of this in the rationale for electing to listen to pipe band music, this is also a very interesting finding and one that should not be dismissed simply because it's roots do not lie directly in the music perception (i.e. sensory experience) of CIUs.

Results from the pre-adolescent group also show that there has been a decrease in the number of participants who choose not to listen to any music, since receiving their implant. This is, however, a far smaller decrease than in the congenitally deaf group, again, consistent with the hypotheses and the established trend. It may be proposed that this result may be, at least in part due to the fact that participants in this group have the potential for a reliable memory of pre-implantation/NH musical experiences. This potential memory, due to the fact that it is by definition a memory from before the age of thirteen years old, may be an unreliable one that may have become exaggerated or distorted to give a skewed recollection of the quality of music listening. The disparity between this 'memory' and the implant mediated musical experiences may lead some people to feel disappointed by the sound and experience of music. In other cases, it may be that some participants in this group have no memory of NH music listening meaning that they may react in the same way as people in the congenitally deaf group.

The late deafened group also provide results that are consistent with the hypothesis and trends mentioned above. We observe three times the amount of participants who choose not to listen to music, since receiving their implant, suggesting that participants in this group are the most dissatisfied with the sound of implant-mediated music listening. Again, as is consistent with the hypothesis, these participants are likely to have the most recent and accurate memory of NH musical experiences and, that their current (i.e. post-implantation) experiences of music listening are inferior to those remembered from before their implantation or onset of deafness.

These results highlight the very fact that, within this sample, there is considerable variability in the way that different types of sounds, including music, are perceived. I would suggest that this result also highlights the fact that the personal background of the CIU plays a large role in the post-implantation perception of sounds and thus, in addition to differences in the way that sounds are perceived, there are differences in the way that these sounds are evaluated as a result of such personal/experiential differences.

This interesting similarity across the sample notwithstanding, it would be naive to conclude that such complex issues as musical taste/preference and listening choices, can be governed wholly by the implant system and its effects on the sound of music. There are a number of cultural and sociological factors that are, in many cases equally influential in the music listening choices of CIUs as the realisation of those sounds that are most successfully perceived (see chapter 1 for more details).

On an individual level, however, the music that someone chooses to listen to can serve as a tool with which a listener can construct or manipulate an environment designed to reinforce their personal values or perceived self-image. For example, a person with a proclivity for new artistic experiences may prefer certain musics that "reinforce his or her view of being artistic and sophisticated" (Rentfrow  Gosling, 2004, p2). Music listeners may also seek out particular styles of music in order to invoke, control or maintain particular emotional conditions; for example, individuals of an optimistic mindset may select specific styles of music to listen to that will sustain or perpetuate their sanguine mood and outlook. Although this is a considerable simplification of the complex psychological processes inherent in the formation of people's music choices and, in turn preferences, it is not unreasonable to suggest that there are some links between musical tastes and simple personality dimensions.

Music can be a particularly powerful tool with which people can define them-selves, their relationships and their place within social groups, for example. Through the display of musical taste we may be able to make inferences about the personality and opinions of the listener based on the stereotypes surrounding various types of music. Zillmann & Gan (in Hargreaves  North:1997) suggest simply and succinctly that “the exhibition of one’s musical taste is used to distinguish oneself” (ibid., p173). Again, using music as a way to create a self image and associate (or distinguish) ones self from social groups is a legitimate and common function of music but **does not** rely on the successful perception of the musical/structural elements. That is to say, using the framework suggested in chapter 1, that the sensory experience does not need to be perfect or in any way ideal in order to derive a meaningful musical experience. In fact, the actual musical components of this function of music use are not necessarily as important as the subscription to the ideas, values, fashions or social groups associated with the music, such that in some cases, with regard to this use of music, the musical experience and it’s wider implications do not rely on the successful perception of the musical elements of the recordings or performances, for instance.

When we consider that approximately 35% of the sample report that the successful perception of music is as important to them as the successful perception of speech, we can see that there are obviously a number of people who are not satisfied with the sound of implant-mediated music, hence the decreases in the frequency of elective music listening shown above. However, as has been discussed, this dissatisfaction is subjective and may be based largely on the ability to make a comparison with the experience of NH music listening, something which is also influenced by the social and psychological factors of identity and preference/taste, as noted above.

As with their perception of the change in post-implantation speech perception, the vast majority (97.1%) of the sample note a change in their post-implantation perception of music. When considering the sample as a whole, the majority of those participants who notice a difference in the clarity of this element of music, since receiving their implant, state that the beat/rhythmic elements of the music are clearer now. This is a very interesting result as it is consistent with other research into the perception of CI-mediated music that has shown CIUs to be more successful in rhythmic tasks and to have better overall perception of rhythm when compared to other musical elements (see chapter 1).

This is not surprising when we consider that the nature of signals which consist primarily of rhythmic information. In signals of this type, the attack of each sound very prominent, acoustically, so that the CIU (bearing in mind the processing limitations of the CI system) may be more likely to perceive the onset of each sound and thus may be more likely to discern the rhythmic pattern/information that is being presented. As the spectral information of this signal, (i.e. the actual sound/tone/timbre of the instrument providing the rhythm) is less salient in the process of understanding the rhythm of the music, the signal does not need to be perceived completely accurately for the rhythm to be understood. That is to say, although the CIU may not be able to fully or accurately perceive the timbre (or even, pitch) of the rhythmic instrument due to potential processing deficits, the structure of the rhythm may be preserved and accurately presented to the CIU via their CI system.

Considering the participants in three distinct groups as above (i.e. late-deafened, pre-adolescent-deafened and congenitally deaf), we notice that the results for the questions relating to the perceptual clarity of elements of music is also provide interesting support for the hypotheses (outlined above) relating to music listening.

Table 3.6 relates to the late-deafened group of participants and shows, for both the tune/melodic elements of music and the sounds of the instruments, that more participants in this group find these elements to be less clear, post-implantation. However, for the beat/rhythmic elements of music we see this difference is less pronounced, as expected based on the results from the whole sample and other existing knowledge relating to CIUs beat/rhythmic perception.

Results from both the pre-adolescent-deafened and the congenitally deaf groups, show that the majority of participants in these groups feel that the musical elements are clearer, post-implantation. Again, these findings provide support for the hypothesis regarding the connection between memories of NH music listening. These results show that the majority of those participants who have the most recent memory of NH music listening state that the musical elements are less clear and that those with less recent or no memories of NH music listening report them to be clearer.

As mentioned above, this data was also analysed with regard to the implanted ear of the participants, an investigative analysis based on research that suggests a functional asymmetry in the auditory cortex (Ligeois-Chauvel et al. 1999  2001, for example). Such research suggests that responses from the left Heschl's Gyrus distinguished brief temporal differences and that the right was more sensitive to frequency than the left.

With regard to the changes reported by RH/RI participants, results from this analysis show that the majority (61.9%) feel that the tune/melodic elements of music are less clear since receiving their implant. This is, perhaps, to be expected when considered in conjunction with the hypotheses derived from the research into the functional asymmetry of the auditory cortex that (as noted above) would seem to suggest that the right brain would be more sensitive to spectral information. Although it is a considerable generalisation, it is not unreasonable to suggest that a great deal of sensory input on the left hand side of the body is processed in the right hemisphere of the brain. With this in mind, we can hypothesise that those participants with right hand implants may process more information relating to sound and music in their left auditory cortex. Based on the aforementioned research that suggests that the left auditory cortex is more sensitive to temporal differences (as opposed to spectral), we may be able to reason that the current research supports these claims in a general sense due to the fact that the majority of those RH/RI participants who notice a difference between pre-/post-implant mediated music listening state that the tune/melodic elements of music are less clear, post-implantation.

Interestingly, we see that this is the opposite when we consider the responses of the RH/LI participants with regard to the tune/melodic elements of music. With regard to the hypotheses based on the research mentioned above, we can also suggest that left ear input will be processed in the right auditory cortex (theorised to be more sensitive to spectral and pitch information, rather than temporal) thus accounting for the majority of participants who indicate a positive difference between the perception of tune/melodic elements of music, when comparing pre-/post-implantation music listening.

It is interesting to note that both groups report their post-implantation perception of the beat/rhythmic elements of music to be clearer, something that we can assume to be a general function of implantation as based on information above relating to the favourable nature of the beat/rhythmic elements of music. This is also consistent with the vast amount of scientific and anecdotal evidence suggesting that the processing strengths of the devices that are better suited for processing temporal cues and that, in turn, the rhythm/beat are often the most successfully perceived element of post-implantation music listening.

It must be noted that, with regard to hypotheses derived from this research, I do not believe that we can simply state that since the right auditory cortex is thought to be more sensitive to spectral information that it will, as a result, be more sensitive to melody. Although the spectral information of a signal will relate to the pitches and timbres of the sounds, it does not follow to state that this means that it will be directly responsible for the perception of melody. A melody is not simply an array of sequential pitches but rather a sequence of individual tones of various durations that are heard and understood as a connected and continuous construct, shaped and moderated by rhythm. Although the hypotheses are very interesting and there is apparent consistency (however general) between these theories and the results of the current study, we have to be conscious of the fact that music and sound are multidimensional meaning that it is very difficult to isolate such musical elements as tune/melody and instrumental sounds etc. Also, generalisations, such as those noted above, of the complex nature of the hemispheric differences in the processing of music and musical elements of sound should not be misunderstood or taken on face value due to the interactions between the cortices that may interfere with such theories. However, the fact that we are dealing with a CI population in this case, who (94.2% of which) have one implanted ear with no hearing aid support is interesting as it the sample are actually (largely) only hearing through one ear, thus only receiving auditory input via one side of their body.

With regard to the evaluation of the sound of musical instruments (post-implantation), the responses were very interesting in that they suggest that participants have a general preference for instruments that are percussive in nature and those that are generally low-pitched e.g. drums, bass guitar, percussion, cello, tympani, the low-end of the piano etc. Instruments that were reported as sounding bad were generally instruments which produce high pitches e.g. high pitched woodwind instruments, the high-end of the piano, flute, whistle, xylophone church organ etc. Some participants (albeit a minority) report that all musical instruments sound bad to them. This element of the study also highlighted some variability in the sample, as there were instruments that were reported to sound both good and bad by different participants, including, the bagpipes, the violin and the guitar.

### 3.4.3 Music Performance (Including Singing)

With regard to the music performance experiences of the participants, a small minority noted that they played and received tuition on a musical instrument and only one of these people has continued to play in public (piano for a church choir); a result is consistent with the hypothesis noted above. If we consider this with regard to the framework for musical experience proposed in chapter 1, it may be conceivable to think that this CIUs post-implantation involvement with music may be, in no small part, due to the fact that it allows the participant to continue to attend the church choir and maintain the role as the group's accompanist; something which may have a function that relates to the category of social experience more than the other two proposed categories (see chapter 1, for more information). That is to say that this person's involvement with music was obviously of a very sociable nature and the context in which it took place (church) has a strong role within some societies and groups of people. Regardless of the quality of the post-implantation sensory experience of the music, this situation and this type of musical involvement obviously provides a meaningful musical experience.

Also, none of the participants have started to learn or to play any other instrument since receiving their implant. In addition, the majority of the participants (58%) report that there is no difference in their pre-/post-implantation enjoyment of singing and a large proportion of the participants reported that they have never been able to sing. However, 27.5% state that they preferred singing more before they were implanted.

This post-implantation decrease in musical involvement was expected, based on existing research relating to the music perception of cochlear implant users and their musical activities, see chapter 1 for more information.

### 3.4.4 Free Response Analysis Discussion

This element of the questionnaire was optional, hence there is not a response from each of the sixty-nine participants (See appendix C, for a complete list of the responses). As this questionnaire was designed to probe the musical experience of CIUs, as described by the framework set forth in chapter 1, this discussion will be presented with regard to the three proposed categories of: sensory experience, cognitive experience and social/environmental experience.

**Congenitally Deaf Group:**

Considering the nature of this group and the history of their deafness we can conceive of a group who, by definition, do not have experience of pre-implantation normal hearing. This lack of ability to compare normal hearing and implant-mediated music listening experience, as discussed above, may contribute to the largely positive appraisals of post-implantation musical sounds of congenitally deaf CIUs. For this group, we can see that there is a generally positive view of musical experience, in comparison to that of the other groups, below. Despite this, it is apparent that there are a number of issues, which relate to the category of sensory experience and the way in which this impacts on general musical experience.

One of the main issues relating to the category of sensory experience reported by participants in this group is the perceived 'clarity' of the music. Such issues are represented by those responses that contain adjectives such as noisy, distorted, messy and buzzy, for example. In a number of the responses noted above we can see that this seems to be related to the ability to hear the lyrics or the sound of individual musical elements. Additionally, it is suggested that problems with the 'clarity' of music may relate to the volume of the music or the size of the ensemble playing it, such that the louder the music or the larger the ensemble (which is also likely to have volume related effects), the less clear the perceived sound of the music. This is, according to knowledge of the functionality of the CI system, not particularly surprising due to the comparatively small dynamic range of the system and the way in which it processes sounds of a musical nature (see chapter 1 for more information).

It was noted above that there is a presumed connection between speech and singing such that singing can, on a basic level be considered as musical/sung speech. With this in mind, it was very interesting to find that one participant reported that they can understand almost all of the words in rap music, if they follow written lyrics while the song plays. The fact that rap is usually performed in a manner that could be described as rhythmic speech, (i.e. very little pitch information presented) may be a benefit to CIUs.

With regard to the report about loud music in social situations such as pubs or nightclubs, for example, it should be noted that these problems are probably compounded by other ambient sounds such as people talking or noises caused by glasses, crockery or cutlery, for example, causing more ambient sound which may be perceived as noise in such situations. In addition to this impacting on the category of sensory experience, there may also be a strong impact on the category of social experience due to increased problems with aural communication that may become apparent in such situations.

**Pre-Adolescent Deafened Group:**

With regard to the category of sensory experience, one interesting theme, which can be drawn from the responses of the pre-adolescent group, is that they are particularly pleased to be able to hear certain sounds. Examples given are 'higher frequency sounds' which had been difficult to hear prior to implantation including birdsong, for instance, a very common effect of some types of deafness due to the perception of higher frequencies being diminished first. It is not uncommon for CIUs or hearing aid users to report that they are delighted with the return of these sounds and, consequently, the relative quality of these sounds is secondary to simply having access to them again. This is echoed to an extent by someone who reports that despite missing the ability to hear music, they find that they cannot complain since the CI has given access to relatively subtle ambient sounds such as 'birds chirping, trees rustling, sound of water running, cat purring'. Again, the 'overwhelming' pleasure derived from this can outweigh the disappointment of not being able to hear everything (including music) as clearly as one might wish.

As with the congenitally deaf group (discussed above) another issue that is raised frequently is the perceived ‘clarity’ of the music. Again this is often related to the volume of the music, the inability to discriminate between the various instruments which are playing, or that the ‘background music’ can block out the lyrics to a song, for example. I feel that the tone of the responses from this group is less positive, in general, than that of the congenitally deaf group who, despite noting some problems with the sensory experience, had a relatively positive view of music. This group shows responses that mention ‘frustration’ and ‘disappointment’ and even ‘regret’, for example, but it is interesting to note that there also seems to be a genuine desire to hear music more clearly or more naturally. One participant even reported that if they knew that they would not be able to listen to Elvis, for example, as a result of the implant that they may not have decided to have the surgery – something that clearly demonstrates the importance of music in this person’s life.

A number of issues relating to the second proposed category informing musical experience (cognitive experience), are reported by this group. One issue, which presumably also relates in part to the sensory experience, is that pitch is reported to sound ‘funny’ and ‘unnatural’ so that music sounds ‘off key’ or ‘out of tune’. This may be caused by the functionality of the implant system or due to individual CIUs’ history of deafness/implantation, for example, although the exact causes would require investigation far beyond the scope of this thesis. However, it is important to note that the accuracy of pitch perception is reported to have an impact on the musical experience.

Recognition is another issue that relates to this category and one that is often reported as problematic by participants in this group. A number of people stated that they find it difficult to recognise music based on the acoustic signal alone and that they sometimes rely on others to inform them of what music is being played. Others report that they are able to recognise songs and hear them more clearly if they have a note of the lyrics and are able to follow them as the music plays (including musical theatre performances) or, if they are able to memorise them in order to have an idea of what is being sung.

In relation to the third proposed category informing musical experience, namely social/environmental experience, there are a number of interesting responses. As with the previous group it is suggested that the experience of music in clubs or at gigs can be problematic. Again, this may be mostly related to the sensory experience due to the CI system's incapability to accurately and successfully deal with sounds of this volume, for example; however, this potentially has a great deal of impact on the general musical experience.

Music in a social situation is also mentioned by one participant who reports that his/her friends, who were music fans, did not understand why he/she did not listen to music. After receiving the CI they began listening to music having 'realised what they were missing'. This is particularly interesting as, in this case, we see a CIU stating that they felt that they were missing out on musical experience and that the CI has helped them to be able to have this experience and to share the musical experiences of their music fan friends.

**Late Deafened Group:**

The respondents in this group, as has been illustrated above are typically those with the least positive musical experiences as is indicated by the marked difference between pre and post-implantation elective music listening frequency, for example. This is echoed in the results that outline the clarity of musical elements such as beat, melody and instrumental sounds. The free responses on music (above) provided by this group also suggest that this is the case, perhaps to a greater extent than any of the other groups. A number of participants talk of being able to 'tolerate' music or talk of feeling as if they have to 'persevere' in order to be able to hear music as anything other than noise, for example. This not only illustrates the type of problems which this group has with music but also that the experience of music is something which many participants would like to have and are willing to work to achieve. This said, however, it must be made clear that there are those who report positive musical experiences and who write favourably about the perceived sound and their experiences of music.

Considering those comments that relate to the sensory experience, as a contributor to general musical experience, we can see that this group also presents many of the same issues that have been discussed above. One such issue is the perceived clarity of the musical sound, with this group also suggesting that music sounds like noise, or that certain elements of the music are obscured or distorted, for example. An interesting observation is made by one participant who reports that when the music is too loud it hides the vocals because the implant cannot 'tell the brain to differentiate the noises', which suggests an awareness that the CI system does not function in the same way as a normally hearing auditory system.

A number of participants from this group suggest that the musical experience is improved when there is a multi-sensory experience, such as the ability to see the music being performed. This is represented by those participants who report that they like to see singers singing, or that they 'understand' music better when they can watch it on television or at the cinema, for example, rather than just hearing it through a hi-fi. This is something that is often reported by CIUs in conversations about music listening and it is suggested that, for those who find music listening challenging, the ability to see the music being performed provides extra information such as clues regarding the instruments playing and their physical location, for example (see chapter 6, for more discussion on this matter). That is to say that if a musical signal is poorly perceived or confusing, then the visual cue of watching it being played might help with the general sensory experience of the music. For example, the sound of a guitar may not be recognisable by the acoustic signal alone but the combination of seeing a guitar and the physical gestures required to play it, coupled with the sound it produces, may make it easier to make sense of and engage with the music. I.e. that which may have been perceived simply as noise may, as a result of the ability to see and understand it as a musical gesture, come to be understood as music.

Considering the cognitive experience (as one of the three categories potentially contributing to the general musical experience) we see a similar reference to memory as was reported by the previous group. In many cases, similar comments were made about the fact that it is easier to recognise or even ‘understand’ music that was familiar from before deafness/implantation. It is also reported that unfamiliar music can be unintelligible and may just sound like noise whereas, although also potentially difficult to perceive accurately, music that is familiar is more likely to be recognised and perhaps even enjoyed. For many people, this seems to impact on the types of music that they are able to engage with, such that it is common for people to report that ‘new’ or ‘current’ music is difficult to ‘understand’ or ‘make sense of’.

Additionally, comments from this group reveal not only an understanding of the difference in the functionality of the CI system compared to the normal hearing auditory system but also, an awareness of cognitive issues. This is exemplified by comments such as, ‘I did persevere on the assumption that the brain could be ‘tricked’ into hearing known tunes’ and also that previous experience may impact on the relationship with music, ‘I wonder if because I was musical that this is my problem? I know and remember what it should sound like.’. Responses such as this, which suggest a discrepancy between the memory of certain pieces or styles of music and the implant-mediated perception of such, are very common – particularly from those CIUs who became deaf later in life. Again, as has been discussed above, it is reasonable to suggest that this group is particularly prone to having a less satisfying experience of implant-mediated music as they are likely to have the most recent memory of normal hearing musical experiences.

With regard to the social experience, this group has respondents that suggest that their social lives and social interactions have been affected in some way as a result of their connection with music. This is best exemplified by one participant who suggests that they miss music and feel that they do not socialise in the same way because they 'can't hear music'. For this person, music is associated with such social activities as singing in church, dancing, the theatre and the cinema, for example, and being unable to engage with music in such settings impacts negatively on the experience.

Conversely one participant, who reports that they have spent time building a 'tolerance' for music, states that being able to hear music again has been very 'emotional' and 'thrilling'. The lack of access to music before the implant made the participant realise that they were 'outside' or 'uninvolved' in social situations such as religious ceremonies. Interestingly, in this case, the participant links the idea of emotion at such ceremonies to the sounds, including music, and states that they 'should have been moved' but was not because of the lack of sound; since receiving the implant and building up tolerance the feel that they can enjoy them emotionally.

## 3.5 Conclusions

Results from this study show that there is a great deal of variability, with regard to the musical experience of the participants and that this variability relates to each of the three categories which I propose inform the general musical experience, namely, sensory, cognitive and social/environmental experience (see chapter 1). By way of framing this within general aural experience of the participants, we notice that the wide range of of implant-mediated musical experience exists within a sample of CIUs with a generally high level of speech perception, suggesting that the level of speech perception does not necessarily correlate with the musical experience of participants.

With regard to music listening, there is a general decrease in the frequency with which the participants choose to listen to music, however, this decrease is not universal and is, in some cases not representative of all participants. With regard to the issue of elective music listening frequency and of the evaluations of the musical experience, a trend can be observed when considering the responses of three distinct groups within the participants, i.e. those who either late-deafened, pre-adolescent-deafened or congenitally deaf. The trend is that those participants with the most recent and (presumably) accurate memory of NH music listening, the late-deafened group, tend to give the least favourable appraisals of implant mediated musical experience and show the greatest decrease in the frequency with which they chose to listen to music. The pre-adolescent-deafened group, i.e. those participants who, on average, have less recent memory of NH music listening give a more favourable evaluation than that of the previous group and, although they show a decrease in their elective music listening frequency post-implantation, this decrease is less than that of the late-deafened group. In addition, the congenitally deaf group, who (by definition) have no memory of NH music listening show the most favourable evaluations of music and results show that, in general, this group now chooses to listen to music more frequently, post-implantation.

Such results suggest that there is a connection between memory of NH music listening and evaluation of implant mediated musical experiences such that the more recent the participant's memory of NH music listening, the more likely the participant will have a negative impression of the sound of music, post implantation. This is not surprising when we consider the wealth of anecdotal evidence and research findings stating that CIUs suffer from poor perception of music, particularly with regard to pitch and timbre. For late deafened users, the comparison of the implant-mediated signal and their memory of NH music listening is likely to result in the poor evaluation of music, post implantation. For congenitally deaf users who are unable to compare the sound of music via their implant with the sound of NH music this problem does not exist and they are therefore not disappointed with the sound of implant-mediated music due to the lack of ability to compare it to NH musical experiences. In many cases these participants state that having never had the opportunity to experience music, prior to implantation, that they are simply glad to be able to hear it at all.

This should not be misunderstood to mean that congenitally deaf CIUs can hear music better (i.e. that they have a fundamentally better sensory experience) than those who have been deafened later in life. It simply suggests, based on the results of this study, that evaluation of the experience of implant-mediated music varies depending on the nature of the participant's deafness and their ability to compare the post-implantation sound of music to their memory of NH music listening.

Despite variability in the perception of post-implantation musical experiences many people are unhappy with the way in which they perceive and experience music in everyday listening situations. A large proportion of the participants now choose not to listen to certain styles of music and many do not listen to any music at all, as a result of poor post-implantation musical experiences. Some participants have stated that this is due to the way that certain instruments sound or that certain instrumental sounds spoil the overall sound of the music that they chose to listen to, eventually leading to them avoiding this, or in some cases, all types of music. Although this was a commonly reported problem, the causes of this problem (i.e. specific instruments or sounds) were not universal, suggesting that this is another element of variability amongst the participants.

As a result, I believe that any attempts to improve the sensory and cognitive experiences of CIUs, specifically with regard to their impact on the general musical experience, should be undertaken on an individual basis as it is clear (from the results of this study) that despite some trends amongst the participants, implanted individuals have different specific problems that need to be taken into account on a case by case basis in order to arrive at a useful and appropriate solution.

With regard to the general musical experience, as outlined in chapter 1, it is important to understand how each of the proposed categories (sensory, cognitive and social/environmental experience) informs this and that this a complex issue which is a result of a coalescence of very personal and individual experiences. Results from this study suggest that, although some musical elements may be difficult to accurately perceive, or that the effect of memory/expectation may also play a strong role in the assessment of musical experience, the general musical experience is not always regarded as negative. It is apparent that the ability to engage with and enjoy music (in both consumptive and participatory senses) is something that many participants miss and would very much like to (re)gain. By considering the factors that contribute to the musical experience and approaching them in an appropriate manner that considers their nature and impact, I believe that it is possible to provide ways to build on and further improve the musical experiences of cochlear implant users.

With this in mind, the following two chapters outline the development and implementation of a multi-channel mixer system which was designed in order to provide CIUs with the opportunity to manipulate the sound of complex multi-channel music. As was noted above, results from this section suggest that, despite group similarities, the musical experiences of CIUs are very personal and individualised. These results coupled with conversations with CIUs during my internship at the HRF (see chapter 2) have shown that in order to meaningfully improve the *sensory* experience of music for CIUs (see chapter 1), as a contributor to their general musical experience, it is important to deal with the relevant issues on an individual level. Given the wide variety of musical experiences and the many factors which contribute to the formation of this, I believe that it is important to provide the opportunity for individuals to be able to control, influence or manipulate elements of *their own* experience, hence the development of the mixer application as discussed in the following two chapters (4 and 5). Chapter 6 then describes the composition of a ‘musical’ in order to outline it’s contribution to the sensory, cognitive and social experiences by way of informing the general musical experience.

# Chapter 4

# Design and Development of a Multi-channel Mixer System

## 4.1 Introduction

As the results from the MEQ suggest (see chapter 3), many cochlear implant users state that music listening is something that some people find difficult or problematic for a variety of reasons. Although poor music perception, and the consequential decrease in elective music listening frequency that many CIUs report, is a common problem, the nature of this issue is by no means uniform. Problems in implant-mediated music listening affect different people in different ways and, due to the considerable amount of individual variation between CIUs (processor, electrode array insertion depth, nature of deafness, single/bilateral implantation, age at onset of deafness, duration of implant use, duration of pre-implant deafness, for example) it would be very difficult to conceive of a single solution that would remedy the wide range of problems associated with the music listening experiences of CIUs, particularly with regard to the sensory experience of music (see chapter 1).

Results from the MEQ (see chapter 3), and information gained from CIUs during my internship with the HRF (see chapter 2), shows that it is often the case that the interaction between signals (i.e. different instruments, for example), and inevitable dominance of some signals over others, is problematic to the listener in many types of music, including commercially available recordings. This problem was reported by a number of participants in the MEQ study (see chapter 3) but the specific details of the problem seem to vary widely, meaning that any steps (other than those related to implant-design) taken to solve or improve this situation would need to address the specific needs of *individuals*, rather than CIUs as a general group, particularly with regard to improving the sensory experience.

Interviews/conversations with CIUs and the MEQ responses (see chapter 3), often included CIUs mentioning that the sound of particular instruments can be problematic for them when listening to music.[1] Although the problematic instruments are not the same in all cases, information gained from the sources noted above shows that some CIUs feel that their music-listening would be improved in some way if the offending instrument was removed or less prominent. Such information led me to the idea that it might be possible to provide CIUs with the opportunity to manipulate the sound of music in order to make it more suitable for their listening needs. Consequently, I realised that if CIUs were given the opportunity to manipulate the way that the music sounded to them, with regard to the mix of the recorded sounds, that they may be able to derive more pleasurable/meaningful musical experiences. For exploratory purposes, an application was designed that allowed CIUs to alter a number of parameters via a simple mixer-based graphical user interface (GUI), to create a 'mix' of music that was more suitable to their unique needs.

In the interests of clarity, when referring to 'mix' and 'mixing', throughout this thesis, I refer to the way in which the various elements of multi-channel music are manipulated and combined in order to produce a composite signal, perceived as the total representation of the music. Since the 1930's, when stereophonic recording was pioneered (Roads, 373), most recordings (certainly in the commercial arena) have been mastered in two channels. Although multi-track recording (i.e. the process of recording) has become almost universal, music is still generally distributed commercially as stereophonic (stereo) recordings, i.e. two-channels, left and right (for example) which gives the impression of sound coming from various directions, as in natural hearing. In this case, the various levels (volume), stereo positions and processing of the original signals are set so that listeners have no control over the mix that they hear; this is set firstly by mixing engineers and producers, then mastering engineers before the record is committed to which ever medium it is distributed on, e.g. CD, vinyl, tape etc. [2]

[1] See chapter 3, table 3.3.3 for examples.

[2] Some home audio equipment has equalisation (EQ) controls with varying parameters that afford the

Therefore, providing CIUs with the ability to access the original signals of recorded music is something that could potentially be extremely useful in understanding implant-mediated music listening with regard to the way in which various signals are perceived. The implication for the potential improvement of the musical experiences of CIUs is that this system will provide the opportunity to either boost areas of the music that are well perceived and enjoyed or to attenuate those areas that may be causing problems or interfering with other parts of the music (both in terms of instrumentation and the shape of the spectrum, see below), for example.[3]

The chapter outlines the purpose, development and potential of this application and will discuss its conception and design with regard to the way in which it functions and the effect it has on the sound of recorded music. With regard to the use of this application as an exploratory tool, the following chapter will describe it's use in a study of music listening experiences.

## 4.2 Application Design

### 4.2.1 Design Aims

In designing and developing this application, there were three main aims, namely:

1. That the system would allow the manipulation of individual channels of audio and allow filtering on each channel.
2. That the system would store the data acquired during the user's session for analysis.
3. That the system would be user friendly and be seen as an enhancement to the musical experience of the users.

With regard to the aims of this application for research purposes, I wanted to explore the following questions:

listener the opportunity to alter the sound of the recording. However, this is a global EQ that applies to the entire stereo mix and is not designed for the same purposes as mixing EQ, rather to shape the spectrum of the mix in a way that will compensate for the frequency response of the system's speakers or resonances of a particular room, for instance.

[3]Additionally, this program has the potential to be developed as part of a music rehabilitation program. More information will be provided on this in the next chapter, subsequent to the presentation of results for this study.

1. When presented with the opportunity to manipulate individual channels of multi-channel music, do CIUs mix differently to CIUs?
2. Is there variability in the way that individual CIUs mix music?
3. Does providing an individualised approach to the mix of multi-channel music improve the musical experience of CIUs and, if so, in what way?

As a result of these aims and questions, the mixer was designed in such a way that it would be simple for users to operate but that would output sufficient data from a user's session to facilitate analyses that would answer these questions. With regard to the first two aims, these objectives have been met and the mixer functions in the desired manner, as discussed below. Results from the study in which the mixer was used show that the final aim was met as users found the application easy to use and beneficial to their musical experience (see chapter 5 for more details).

### 4.2.2 Application Development

I will firstly present an overview of the design features and capabilities of this application from a technical perspective, before progressing to discuss its role in the study. This application was developed using MAX/MSP, a visual programming language for music and multimedia made by Cycling '74.[4] MAX/MSP has come to be used widely by software designers, performers and composers, for example, and was particularly well suited for the design of this application due to it's ability to create a GUI that would handle the manipulation of multi-channel audio and the creation/collection of data simultaneously.

The application gives the user the opportunity to mix multi-channel music by manipulating some basic features of the sound (outlined below) of separate channels of music. This results in the user having the ability to create unique versions of specially designed multi-channel music, based on their personal listening needs using controls have been designed to be as simple and user friendly as possible and to be familiar as a result of their similarity to many commercial devices (see figure 4.1).[5]

Before continuing to discuss each of the mixer's controls individually, I will give a general overview of the system, with specific regard to signal path and to give a general

[4]For more information and documentation see: http://cycling74.com

[5]The mixer was designed to work with pieces of music with 6 channels of audio. This decision was taken for practical reasons based on the stimuli being presented in study (see below).

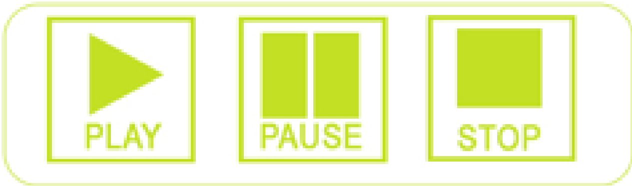


Figure 4.1: Mixer's transport controls

outline of its functionality. Figure 4.2 shows a basic outline of the signal path of the mixer application.

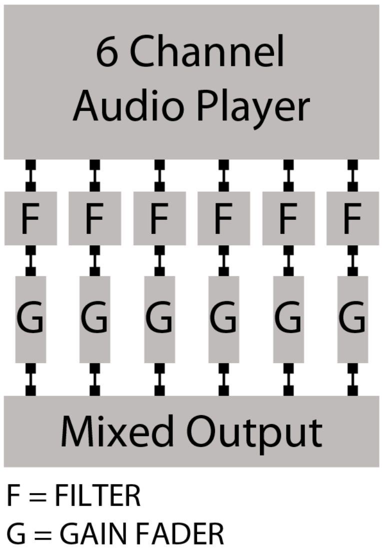


Figure 4.2: Mixer's Signal Path

As can be seen, 6 (mono) channels of audio leave the source, in this case a digital multi-channel audio player, and are then fed into six separate filters. These filters are, in their default state, set to let the audio pass without boost or attenuation (bypass), until the user operates the controls, at which point, the audio becomes affected by the filter. From the filter, the audio arrives at a volume slider that can boost or attenuate the entire signal of that channel, as opposed to specific areas of the spectrum as in the filter (see below for more details on the filter used in this application). When the audio leaves the volume slider, it is fed to the output along with the rest of the channels; the output is, therefore, the mix created by the user.

### 4.2.3 Volume and Gain

This parameter is one of the fundamental elements of this application as it is likely to be one of the main user-modified parameters that will affect the sound of the mix that the user hears, i.e. the relative volume of each of the signals. The volume of each channel is controlled via a vertical fader see figure 4.3. This is not the gain of the filter but rather the level of the channel's signal (post filter). This stage of the signal path can be considered as a scaling stage in that this feature provides the opportunity to raise the level of the complete signal of a channel, not specific sections, as in the boost/cut controls of the filter.

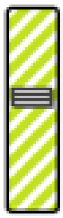


Figure 4.3: Gain Fader

When the fader is at 0 (the bottom of the throw), this produces a zero signal, i.e. silent. This is the default state of each fader so that when the music begins the user has to raise the level of each in order to hear any sound. This was an intentional decision made to avoid the user being bombarded with music that may be unpleasant or uncomfortable. By allowing the user to raise the levels, they are free to explore the various sounds of the track at their own pace and without fear of sudden excessive volume.

With regard to the construction of this stage of the signal path, the fader should be viewed as a scaling tool that allows for the signal to be increased or decreased at the users will. The (MAX/MSP) gain fader functions as a sliding scale from 0 to 158 and multiplies the signal by 1 (i.e. 0dB) when the fader is set to 128. Thus, we can consider this a scale of 0% – 100% (i.e. 0dB) with the potential to be multiplied to 300% (approx).[6] When the fader is set to it's maximum (a value of 158), the signal has been scaled so that it is 17.4dB louder than the input volume (i.e. that of the source signal). Therefore, we can say that if the fader is set to 128 the signal (post filter) is not being either boosted or attenuated. Values above this number boost the signal to a maximum of 17.4dB and values below cut the signal to a minimum of -76dB when the fader is set to

[6]All information relating to the function of the gain fader relates to it's functionality in MAX/MSP. Further information on the Gain object can be found in the MAX/MSP documentation.

1. As noted above, when the fader is at zero, there is no signal passed and the channel is entirely silent and no audio can pass.

For each of the mixer controls in this study, the only visual representation of the functionality that users were given was the vertical or horizontal position of the slider/fader-bars, respectively. There were no visual indicators such as LEDs monitors or VU-style meters that can indicate issues such as whether a signal is too high, for example. This decision was taken to ensure that the participants were mixing based on what they were *hearing* and not trying to conform or adhere to (either subconsciously or deliberately) any standards or ideal positions as determined by visual feedback from VU meters or LEDs signalling clipping or distortion, for example. By eliminating such visual feedback we could be more certain of the fact that participants were creating their mixes based on the way that the music sounded and not being influenced by meters, for example. This applies to each band of the EQ, and the gain slider for each channel, in addition to the combined output of the six channels collectively.

### 4.2.4 Frequency Response, Filters and Equalisation

When describing the character and function of a filter it is common to make reference to the 'amplitude-versus-frequency response' (frequency response), of the filter (Roads, 185), which relates to the accuracy of sound reproduction, relative to the function of the filter. Frequency response can be used to measure or describe the spectrum response of an audio system and typically relates to the comparison of the input and output of such a system. The most accurate frequency response, i.e. that which provides the most accurate sound reproduction (output relative to input), is characterised by a straight-line graph 'which indicates a linear or flat amplitude across the frequency spectrum' (ibid.); see figure 4.4.

As we can see from figure 4.4, almost all the frequencies within the range of the audio device pass without being either attenuated or boosted. This is a hypothetical representation of a linear frequency response but in reality, as a result of the interaction of physical components (e.g. circuitry or valves), audio devices have frequency responses that are not entirely flat (hence nearly-flat). As this means that there will be some alteration to the spectrum of the signal, (boost or attenuation at certain frequencies, usually the extremes) the audio device inadvertently acts as a filter for the signal.

The frequency response of a filter is determined by a number of properties, however, the


Figure 4.4: (Nearly) Flat Frequency Response Curve

three most pertinent to this application are, the centre/cut-off frequency, the quality factor (Q) and the gain.

**Gain (with regard to the filter):**

The gain of a filter is the amount of cut or boost of a frequency band which, when considering the response curve of a filter, is shown by the height/depth of the peak/trough or shelf.

**Centre/cut-off frequency:**

A filter's centre frequency is the centre point between two cut-off frequencies. That is to say that the centre frequency is the point on which the filtered section of the signal is centred, i.e. the mid-point in a frequency response curve (see figure 4.5).

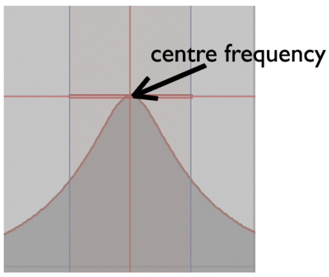



Figure 4.5: Centre Frequency Illustration

**Quality factor (Q):**

Quality factor (Q) can be considered as the parameter of a filter which relates to the width of the curve; something that translates in a less abstract sense to the bandwidth. The higher the value for Q, the narrower the bandwidth (and vice versa), meaning that a filter with a high Q affects a smaller range of frequencies than a filter with a low value for Q which allows a greater frequency range to be exposed to the filter. An alternative way to consider the nature of Q is that it relates to the level of resonance in a filter system. As mentioned above, when Q is high, a small range of frequencies (focused on the centre-frequency) are exposed to the filter, this means that the frequency response curve is focussed tightly around the centre (resonant) frequency (Roads, 1996).

Having discussed the nature of the three most pertinent elements of the filter system, namely; volume/gain, centre/cut-off frequency and Q, I will briefly outline the notion of 'spectrum-shapers', with regard to filter-banks and equalisation (EQ) systems in general.

Filter banks are sets of filters, typically narrow band-pass filters set at a specific frequency (ibid., p193), that are exposed to the same signal in parallel. The typical output of such a system is the combination of the filtered signals. If the level of each of the filters can be controlled individually the filter bank can be referred to as a spectrum shaper because the parameters are used to modify, or shape, the spectrum of the input signal. Depending on the nature of the filter bank and its parameters, spectrum shapers can be used to modify the original signal so dramatically that certain areas of the spectrum can be significantly boosted or attenuated so considerably that that the energy in such an area is virtually removed.

The terms 'spectrum shaper' and 'equaliser' can generally be considered to be synonymous, however, 'equaliser' is derived from the an early application whereby equalisation was used to compensate for irregular frequency responses in telephone or public address systems, for example (Fagen, 1975; in Roads, p195). Personally, I feel that the term 'spectrum shaper' is a particularly helpful one when considering the effects that the EQ system of this application has on the input signal. To consider the input signal being shaped or moulded as a result of the user manipulating the controls in a way that suits their specific and unique needs is very appropriate, in this context. From the perspective of audio engineering, however, the term equaliser is the dominant one and, for the purposes of this chapter, it is worth outlining two main types of equaliser  graphic and parametric.

A graphic equaliser has a number of filters (often something between 25 and 31) with fixed centre-frequencies and bandwidths that are typically one-third of an octave (ibid.), and a fixed Q.[7] The level of each filter is either cut or boosted within the specific frequency bands meaning that the spectrum of the input system is shaped by the EQ system, based on specific parameters. A parametric equaliser, however, typically

[7] 1/3 octave band correspond roughly to one critical band

includes fewer filters (often three or four in parallel), but each filter has more flexible controls for the parameters mentioned above (center frequency, the Q, and the gain of each filter). The filter system used in the application described in this chapter does not strictly fit into the category of graphic or parametric but is used to shape the spectrum of the input signal (of each channel) based on a three band model with a fixed Q and centre/cut-off frequency with 12dB of cut and boost available for each band. The decision to allow users to make up to 12dB of boost or cut on each of the bands was to provide the opportunity to considerably alter the perceived sound of the source signal in each band.

For ease of use, this feature of the mixer is limited to a simple 3-band boost/cut EQ system that is controlled by 3 horizontal sliders on each of the 'channel strips' as shown in figure 4.6.

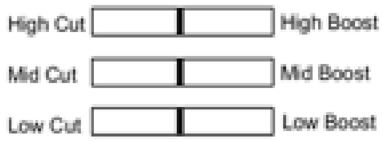



Figure 4.6: 3-band boost/cut EQ

A movement of the control to the left will cut the energy in the frequency band associated with the fader that has been altered. Conversely, if the control is moved to the right, this section of the signal will be boosted. As this is a sliding scale, the user is able to determine the degree to which the signal is boosted/cut in any of the frequency ranges dealt with by the controls.

The EQ bands in the pre-pilot testing version of the mixer application were set as follows:

| | Frequency (Hz) | Type | Gain (dB) | Q |
|---|---|---|---|---|
| High | 2500 | High-shelf | +12, -12 | 1 |
| Mid | 800 | Peak-notch | +12, -12 | 1 |
| Low | 200 | Low-shelf | +12, -12 | 1 |

Table 4.1: Filter parameters in pilot study

These figures were initially selected based on discussions with sound engineers and the functionality of audio equipment. However, when considering and conducting analyses on the data gained from the pilot studies, it was realised that the parameters outlined above did not sufficiently represent the frequency range that would be considered, specifically; 100Hz 16kHz. This was revised for the CI study in order for the EQ bands (e.g. high, mid and low) to be more representative of the corresponding areas of the spectrum that would be considered in the analyses (see chapter 5). Therefore, the 100Hz 16kHz spectrum was divided into three bands, approximately, as follows so that the filters actually affected the area of the spectrum to which they pertain:

| | Frequency (Hz) | Type | Gain (dB) | Q |
|---|---|---|---|---|
| High | 3174 | High-shelf | +12, -12 | 1 |
| Mid | 1259 | Peak-notch | +12, -12 | 1 |
| Low | 499 | Low-shelf | +12, -12 | 1 |

Table 4.2: Filter parameters in actual study

Again, for ease of usage, these ranges have been labelled as ‘low’, ‘mid’ and ‘high’ as this is presumed to be the way that most people are used to experiencing EQ controls on conventional domestic hi-fi systems, for example. Table 4.3 (below), depicts the nature of the frequency response curves of the three filters used in this EQ system, namely, high-shelf, peak-notch and low shelf.

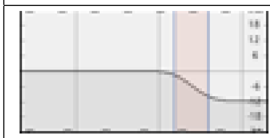
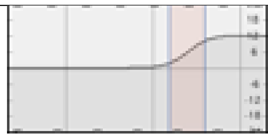
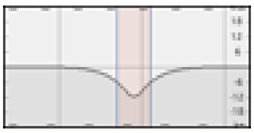
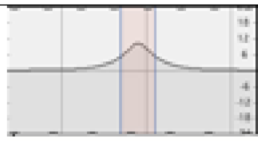
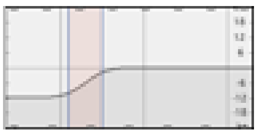
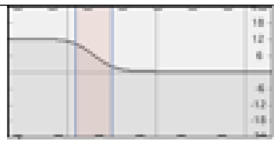
| Cuts | | Boosts | |
|---|---|---|---|
|  | High-shelf filter with 12dB cut from 3.174 kHz. Q = 1 |  | High-shelf filter with 12dB boost from 3.174 kHz. Q = 1 |
|  | Peak-notch filter with 12dB cut at 1.259 kHz. Q = 1 |  | Peak-notch filter with 12dB Boost at 1.259 kHz. Q = 1 |
|  | Low-shelf filter with 12dB cut from 3.174 kHz. Q = 1 |  | Low-shelf filter with 12dB boost from 3.174 kHz. Q = 1 |

Table 4.3: Illustration of Filter Response Curves

### 4.2.5 Pan

When designing this application, another parameter that was considered for inclusion in this program was pan.[8] It was originally thought that it may be useful for CIUs to experiment with the way that signals are located within the stereo field but further consideration of this led to it being excluded at this time for a number of reasons. Specifically, unilateral implant users only hear an implant-mediated signal from one side and experimentation with the location of signals in the stereo field may actually serve to mask, distort or boost signals inadvertently, thus defeating the purpose of the function. This is not to say that the issue of pan is not interesting or worth investigating, it is simply that I believe it to be an unhelpful variable to include in this particular study.

## 4.3 Application Capabilities and Process

This section will summarise the capabilities of the mixer application and will also consider the way that this has been included into this software, designed to assess the music listening experiences of CIUs.

The mixer was designed to be capable of:

- Playing, pausing and restarting up to six mono channels simultaneously.

  Although the user has the ability to alter some basic sonic parameters, as outlined above, they will have no control over any transport features other than the ability to play, pause and restart the track. Therefore, the user cannot choose to return to or loop any specific section of the track, for example. The users have no view of the wave forms so that the use of the program will seem, with regard to transport elements of the program, as if it were similar to playing music on a hi-fi, for example, making the process as familiar and simple as possible. It was felt that too much access to the source signals (i.e. the ability to view the wave forms or to focus on small sections of the audio) would not be beneficial for two main reasons. Firstly, that the experience of using technology to access music in this way would be unhelpfully dissimilar to the way in which most users normally access music. Secondly, for many people, this amount of detail may be confusing and may serve

[8] Pan is short for panoramic-control and is used to change or move the apparent position of a sound between outputs (typically left and right for stereo). In extreme panning, the source is heard from only one output i.e. left or right

to distract the users from the purpose of the experience or provide visual stimuli that are not necessary or appropriate for this function.

- Remaining fully editable for the period of time in which the user is mixing the music before collecting and storing the data.

  All parameters (noted above) remain fully editable until the data is automatically stored when the timer reaches a specific point and the user automatically progresses to the next piece of music. At this point, numerical information that details the user-set parameters is stored to a database before being written to an .xml file upon completion of the session along with the rest of the data collected during the study. The benefit of using this method of data collection is that, throughout the study and in future, the values stored by the user can be recalled and used to reset the mixer to the settings of a previous session so that the user can continue mixing.

- Collecting and storing user data.

  In addition to storing data relating to the mix parameters, other data can be stored and written to the xml file output at the end of the session. Such data includes personal information relating to the user and responses to the post-mixer questionnaire, for example (see chapter 5 for specific details).

## 4.4 Musical Stimuli

As a result of the way that this application has been designed to process audio, the musical stimuli used are original pieces of music, specifically recorded as one track consisting of six mono channels. The decision use six mono channels of audio was made as it was believed that 6 channels (i.e. six separate elements) gives scope for a meaningful exploration of the way that CIUs choose to mix complex multi-channel music. More specifically, six channels allows us to study some important musical elements including, melody, harmony, rhythm, timbre and also the perception of vocals (particularly sung words) in various different modes of presentation. Considering (when designing the stimuli) the way in which such musical elements are presented to the user allows for the comparison of the musical character of the mixes.

The following example is taken from the first piece of stimuli used in the study (see chapter 5 for full details) and illustrates the way in which the stimuli pieces are structured:

1. Drum Kit
2. Bass
3. Piano
4. Strummed Guitar
5. Lead Guitar
6. Vocal

This example tests the way in which several musical elements are experienced in complex, multi-channel music with a typical line up for a rock/pop band.

For example:

The **drum kit** would be providing a large part of the rhythmic elements of the music. This may include general rhythmic features but is also likely to include important fundamental features such as the beat or the pulse of the music.

The **bass** may also be responsible for a proportion of the rhythmic information in the music but it will also have the role of outlining or accenting the harmonic basis of the music.

The **piano** may have the role of working with the bass to outline the harmony but may (typically) also provide some melodic elements, depending on the way in which it is played.

The **strummed guitar** may, for example be producing chords in a rhythmic manner and would this be providing rhythmic and harmonic information in the mix.

The **lead guitar** may be providing melodic material, primarily but may as a result also contribute to the harmonic information in the mix. Therefore, this guitar has a very different, although complimentary role to that of the strummed guitar.

In this example there are two guitars listed. This is due to the fact that, along with the piano and bass (for instance) the guitar is a particularly versatile instrument that is capable of providing many of the musical elements outlined above in different ways, again, depending on the way it is played. This was also noted the participants in the music focus group which took place during my internship at the HRF, see chapter 2.

The **vocal part** is particularly important, as it is usually responsible for carrying the main melody of the music and usually carries the linguistic meaning, the message or the ideas conveyed in the song due to the use of spoken/sung language). This element may be particularly interesting as it will allow for the exploration of the importance of the vocal melody/words and the relation to the other instruments in the track.

Therefore, in order to have some continuity and to facilitate comparison between the 4 pieces of musical stimuli it was decided that each piece adhere to the following model as derived from the example above:

- A primarily rhythmic part (such as drums/percussion etc.)
- A bass line that is typical to the style of the music (bass, cello etc.)
- A 'non-lead' part providing a mix of Harmonic, rhythmic or melodic information (such as, piano, guitar, horns, strings etc.)
- Another 'non-lead' part (as above)
- A lead instrument providing mainly melodic information and in the case of music with vocals, also providing the words of the song.
- A lead instrument that provides information that is secondary to the main melody but that may provide a counter-melody or some other element that conveys stylistic information about the music (saxophone fills, for example). This may not be imperative to understanding the music but it may provide interesting extra information that enhances the comprehension and contextualisation or enjoyment of the music for the listener.

Participants had the ability to essentially mute each of these tracks (by positioning the fader at the bottom of the throw) depending on their personal needs. Therefore, the six-channel model (as described above) simply outlines a maximum possible configuration; the eventual mix, as created by the user, may not contain the sound of the instruments in each and every one of these channels.

As the stimuli are composed and divided into channels based on the model mentioned above, I hoped to draw interesting and rich information about not only the choice of the musical elements, but also the preferences for the various ways in which these elements may be presented. Considering the rich variety of instruments and playing styles that exist, I do not believe it would be sufficient to use fewer instruments/channels and attempt to comment on elements such as harmony/chords, tune/melody etc, as a result of the various ways that information relating to these elements may be presented. Thus by using the model above and a knowledge of general stylistic conventions, we were able to present information relating to important structural features of music in a variety of ways. This coupled with the fact that the user will have the opportunity to choose which channels to include in the mix (by altering the volume of each channel) will provide interesting information relating to their preference for structural or even stylistic elements of music.

## 4.5 Data

As was noted above, upon completion, the program creates an xml file containing all the information collected during the course of the session including personal information relating to; age, nature of deafness, handedness, for example (see the following chapter for a list of the actual questions). In addition to this personal information, this file also contains quantitative data relating to the configuration of parameters that the user generated when creating their unique mixes. This was a numerical representation of the user's mix which, as noted above, can be used for analysis purposes but also as a way to recall the settings of their mix, either for comparison with a future mix or allow for the opportunity where a user may resume a mixing session, if interrupted. Qualitative data relating to the user's experience of using the mixer and any comments on their music listening experience as a result of using the mixer application will also be included in this file. The following chapter describes the analyses performed on this data.

This chapter has dealt with the design, development and implementation of a multi-channel mixer application. The following chapter provides specific and detailed information about the study in which this mixer was used.

# Chapter 5

# Mixer Study

## 5.1 Introduction

The previous chapter (chapter 4) outlined the rationale and technical development of the multi-channel mixer application which was created and used in this study and the data it is capable of producing. The current chapter, however, is specifically related to the use of this application within the context of an investigative study into the way that CIUs (primarily) choose to mix multi-channel music, however a control group of NH participants was also included in the study in order to facilitate comparisons between the groups. As was stated in the previous chapter, the mixer application was initially conceived (during my time at the HRF) as a way for individuals to manipulate the sound of music to suit their own individual listening needs. The idea to develop this application arose, simply, from a conversation with an adult CIU (a very successful user with regard to speech and communication) about his musical experiences during the music focus group in Boston (see chapter 2). This particular man felt that he enjoyed particularly good music listening abilities but was aware that other fellow CIUs were less fortunate than he was with regard to their ability to enjoy music. As the conversation progressed it became clear that there were certain musical instruments that made music listening problematic, specifically, the piano and violin and he remarked somewhat flippantly that music would be much better if *'. . . you could just turn down the sound of the bad instruments . . . or even get rid of them all together'*.

Similar ideas were suggested by CIUs who took part in the MEQ study (see chapter 3), however, despite many users wishing they could remove the sound of a problematic instrument or increase the prominence of a favoured one, for example, the instruments that people would choose to 'get rid of' are largely varied and depend on the musical circumstances/context. Therefore, the idea of being able to manipulate the sound of complex multi-channel music in such a way as is described in the previous chapter arose with a view to improving musical experiences of CIUs and it was presumed, due to the range of instruments/musical elements which are reported to be problematic (see chapter 3), that the most sensible and meaningful way to approach a process such as this is to provide the opportunity to create an *individualised* musical experience. From the point of view of gathering important data regarding individaual differences and group trends relating to musical experiences, however, the use of this application in an exploratory context as outlined in this chapter is also very important.

The individual listening needs/characteristics of CIUs are exceptionally difficult to quantify and describe due to considerable variability. However, highlighting the wide range of results which have been garnered from this study is important for two main reasons: firstly, that this provides support for the argument that (when attempting to improve the musical experience of CIUs) the sensory and cognitive experiences (see chapter 1) should be considered on an *individual* level and, secondly, that an application of this nature can be particularly useful in the improvement of musical experience due to the fact that it facilitates such individualisation.

### 5.1.1 Hypotheses

The hypotheses for this study were drawn from (a) my experiences of observing, interacting and talking with CIUs during my internship at the HRF (see chapter 2) (b) the results of the MEQ study, see chapter 3, and (c) responses to the performances of 'Deacon', both in terms of Plant's questionnaire analyses (see chapter 6) and first-hand communication with CIUs in connection with that work. Throughout this thesis it has been noted that the musical experiences of CIUs vary widely and this has certainly been taken into account in this study, however, it is the case that a number of consistent issues are noted which seem to relate to improved or positive musical experience. From these consistent issues, which include proclivity for rhythmic music or lower-pitched musical sounds, for instance, it was possible to draw a number of hypotheses with regard to the results of this study and their potential impact on the musical experience of CIUs.

More specifically, it was hypothesised that:

1. There would be significant differences between the long-term average spectra (LTAS - see below for details) of the CIU and NH groups. Specifically, that the LTAS of the average mix (whole piece) by the CIU group would display a preference for lower frequencies over higher frequencies.

2. Participants in the CIU group would choose to include fewer channels in their mixes than the NH group.

3. The musical character of the CIU mixes would highlight those musical elements frequently reported to be well-perceived by CIUs. Specifically, that the mixes of the CIU group would: (a) have a strong rhythmic character, and;

(b) show a prominence of low pitched musical sounds and a bias towards lower frequencies.

4. When asked to compare the sound of user-generated mixes with a pre-mixed version of the same piece of music, CIUs would prefer the sound of their own mix to that of a pre-mixed version of the source signals.

5. That CIU participants would be able to use the controls of the mixer to improve the clarity of a number of musical elements such as beat/rhythm, tune/melody, and instrumental sounds (see description of post-mixer questionnaire, below).

6. That this application would be viewed favourably by CIUs as a tool for improving the musical experience, particularly with regard to the *sensory* experience (see chapter 1).

7. There would be a degree of variability amongst the CIU group with regard to: (a) the LTAS of their mixes and (b) the instruments included in their mixes as a result of inevitable individual differences.

## 5.2 Method

### 5.2.1 Participants

When considering the nature of suitable participants for this study a number of issues were considered in establishing inclusion/exclusion criteria. Firstly, as this study is computer based, participants were required to have the physical ability to use a computer keyboard for a small amount of typing and to be able to use a mouse, which is the main device used to operate the software. With regard to the hearing status of the participants, the only stipulation for the experimental group was that the participants were cochlear implant users and that the history of deafness (e.g. congenital or acquired etc.) should not be a consideration. Also, personal details such as the manufacturer/model of their implant or their speech coding strategy were not considered when recruiting participants. The decision to include CIUs of any nature was taken in order to gain a sample that was not selected based on any such criteria, other than the fact that they use a CI. As this application is focussed on the customisation of the sound of music by *individual* CIUs no other inclusion/exclusion criteria were implemented.

For the NH (control) group the only criterion was that they were normal hearing; i.e. did not have any known hearing issues. The hearing of the control users would be ‘tested’ (see below) during the study in order to ensure that they were indeed suitable to be classed as NH participants. The age of the participants was not a consideration providing they were adults over the age of 16 years old, however, it was noted that some elderly participants may have less prior experience of computer-use and thus may have difficulty participating as a result. One final consideration was that, despite this study’s musical nature, it was not necessary for the participants to have any musical background or training.

The criteria above certainly do not lend themselves to the creation of groups of participants who are well matched for age or gender, for example. Nor does it strive to include participants with similar backgrounds with regard to their history of deafness, implant make/model, coding strategy or any other personal or technological variables (see chapter 1). As with the MEQ study (see chapter 3), I believe that when considering *musical experience* the most interesting and ‘real’ results will be gleaned by observing CIUs and embracing individual variability. Given that the main purpose of this application is for users to be able to tailor the sound of music in a personal and unique manner, this type of approach is the most meaningful (in this context) as it includes a wide range of people with varied backgrounds and experiences, something I believe will *enrich* the results of this study rather than *contaminate* them (as may be considered to be the case in other studies which aim to minimise individual differences in the sample and isolate or control for specific variables).

Participants were an experimental group of 8 adult CIUs aged between 43 and 73 years old (M = 54, SD = 10.14) which comprised of 4 males (50%) and 4 females (50%). The period of time in which participants had been using a cochlear implant ranged from 1 year  16 year (M = 9, SD = 5.04) and the period of pre-implantation deafness ranged from 14 to 38 years (M = 28.56, SD = 8.94). Table 5.1 provides details on individual CIU participants.

| Participant | Age | Gender | Duration of Implant Use | Pre-Implant Deafness | Implanted Ear | Manufacturer | Model |
|---|---|---|---|---|---|---|---|
| CIU 1 | 43 | Male | 1 year | 14 years | Left | MED-EL | Unknown |
| CIU 2 | 48 | Male | 10 years | 38 years | Left | Cochlear | Esprit 3G |
| CIU 3 | 56 | Female | 15 years | 30 years | Left | Cochlear | Esprit 3G |
| CIU 4 | 56 | Female | 10 years | 16 years | Left | Cochlear | Esprit 3G |
| CIU 5 | 63 | Male | 4 years | 31 years | Right | Cochlear | Freedom |
| CIU 6 | 47 | Female | 8 years | 36.5 years | Right | MED-EL | Unknown |
| CIU 7 | 46 | Female | 8 years | 34 years | Right | Cochlear | Esprit 3G |
| CIU 8 | 73 | Male | 16 years | 29 years | Right | Cochlear | Esprit 3G |

Table 5.1: CI Participant Details

All of the CIU participants wore hearing aids prior to implantation and only one has continued to do so since implantation (CIU 6). Three of the CIU participants played a musical instrument before implantation; one played bass in a small group of colleagues (CIU 8) from work, and the others played guitar (CIU 2) and piano (CIU 1) but did not play in groups. None of the CIU participants play an instrument subsequent to implantation.

By way of keeping the demographics of the group balanced, each CIU recruited was asked to bring a NH friend/family member who would also take part in this study as a member of the control group. The NH group consisted of 8 normal hearing adults (three male and five female) aged between 16-59 (M = 39.25, SD = 17.81). Table 5.2 provides details of individual NH participants.

| Participant | Age | Gender |
|---|---|---|
| NH 1 | 59 | Male |
| NH 2 | 55 | Female |
| NH 3 | 16 | Female |
| NH 4 | 42 | Female |
| NH 5 | 47 | Male |
| NH 6 | 23 | Male |
| NH 7 | 18 | Female |
| NH 8 | 54 | Female |

Table 5.2: NH Participant Details

Four of the NH participants have played musical instruments; NH 2 played the recorder and used to play in a recorder group at school, NH 3 used to play guitar but did not play in any groups, NH 7 plays the guitar but not in any groups, NH8 used to play the violin but not in any groups.

A basic hearing test (see chapter 4 for details) was given to NH participants in order to confirm their hearing status. Results from this test would provide a sufficiently accurate indication of the normality of participants' hearing status and would highlight any issues that would render them ineligible to be included in this study as a participant in the NH group. As the only stipulation for inclusion in the CIU group, as noted above, was that participants used a CI, there was no need to subject CIUs to this test.

The results are shown below, which confirm the normal hearing status of the participants in this group, for the purposes of this study. [1]

[1] It must be stated that this was *not* an official medical hearing test, simply a brief assessment based on the style of tests used by audiologists, for example.

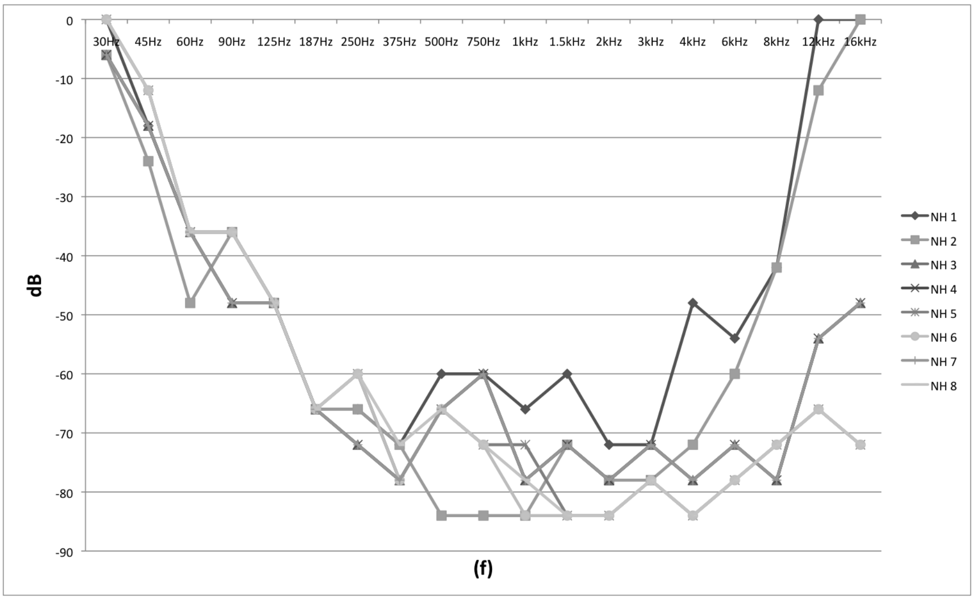



Figure 5.1: NH Individual Hearing Test Results

Figure 5.2 shows the mode of the NH hearing test results.

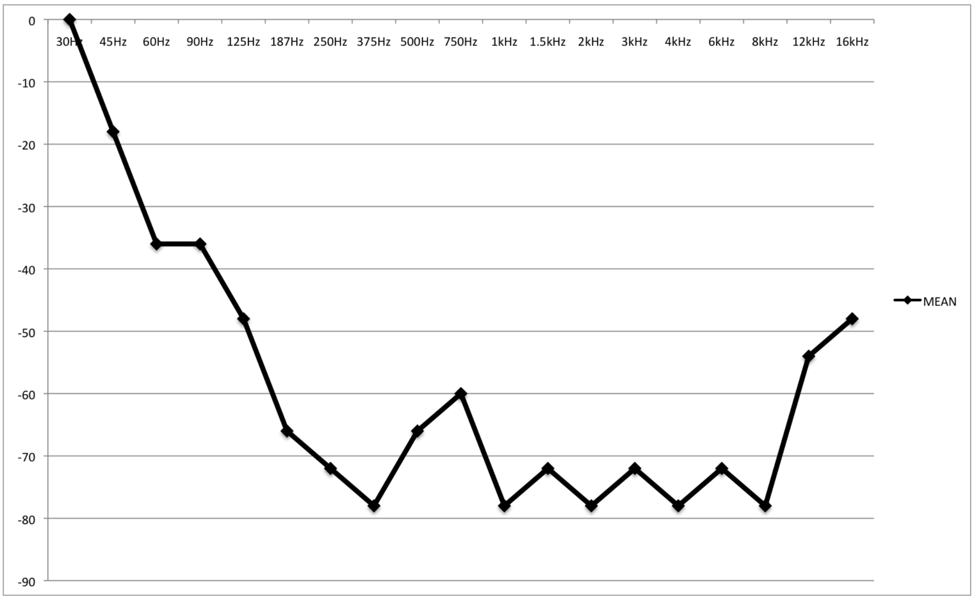



Figure 5.2: Mode of NH Hearing Test Results

Crosses represent the level at which the tones of indicated frequencies were heard. For each frequency, the volume of the tone was increased incrementally until the user noted that they were able to hear it.

### 5.2.2 Participant Recruitment

It should be noted that the recruitment of participants was a problematic and protracted process which yielded eight CI participants (detailed above). This process involved communication directly with the NHS Scottish Cochlear Implant Programme, Deaf Connections (Glasgow-based charity), MED-EL UK (CI manufacturer), 'Southern Bionic Buddies' (CI user group), Southampton Cochlear Implant Programme and personal correspondence with those participants from the MEQ study (see chapter 3) who provided contact details in order to be contacted for the purposes of future research. With each group contacted a number of problems were faced, more specifically:

- **Scottish Cochlear Implant Programme:** During discussions with this programme about the possibility of running this study in collaboration with them, the National Institute for Clinical Excellence (NICE) recommended that paediatric CIUs should receive binaural implants as standard which meant that their workload increased dramatically and, consequently, that they did not have time to be a part of this work. Patient confidentiality meant that it was not possible for this group to simply provide me with the contact details of patients whom I could contact personally.

- **Deaf Connections:** This charity (based in Glasgow) were very interested in hosting the study and assisting with participant recruitment. However, they withdrew this offer due to issues with staffing as a result of recent funding cuts. Again, client confidentiality issues prevented me from contacting potential participants personally.

- **Southampton Cochlear Implant Programme:** This group was contacted when those mentioned above were unable to participate. Although they are a long distance from Edinburgh, they have a group of patients who are reputedly very interested in taking part in research. However, it was not possible to proceed with any work with this group as they are governed by strict regulations related to research and development and ethics procedures. An application process would have taken longer than the time available for this study and was thus not feasible. Staff recommended that I contact the user group associated with the programme, the 'Southern Bionic Buddies'. As with the Scottish Cochlear Implant Programme, patient confidentiality meant that I could not have access to the contact details of individual CIUs in order to attempt to recruit them independently of this programme.

– **'Southern Bionic Buddies':** In order to recruit participants I contacted this user group and was advised to write an article for their quarter-yearly newsletter. I wrote two articles for this newsletter (over the period of six months) and only received correspondence from one person stating interest in participating. Due to the distance from Edinburgh it was deemed impractical to travel to Southampton for the sake of including one participant.

– **MED-EL UK:** Staff at MED-EL UK were contacted when all other avenues (above) had been exhausted (over the period of 12 months, approximately). As this company manufactures and distributes CIs to hospitals, for example, they are governed by many of the same confidentiality issues which made it difficult for me to recruit participants personally. Consequently, this company were also unable to recommend any participants for the study.

As a result of those problems noted above, all participants recruited for the experimental group were recruited via personal contact with those CIUs who had indicated during the MEQ study (chapter 3) that they would be willing to take part in future research. Due to the nature of the MEQ study, the respondents were widely geographically dispersed across the country, again introducing potential travel and logistic problems. As noted above, the control group was recruited by asking the CIU participants to bring a family member or friend, for example to the session who would also be interested in taking part, as noted above. Thus, every CIU participant who attended the study brought an NH participant with them, something which a number of participants were grateful for as it meant they did not need to come alone.

Had the number of participants been greater, it would have been possible to make analyses of both inter and intra-group differences, for example, such as those conducted in chapter 3 in which participants could be divided into 3 subgroups,namely; the late deafened group, the pre-adolescent group and the congenitally deaf group. However, as was discussed in chapter 4, the main focus of the mixer application which is at the centre of this study is it's potential benefits for the *individual* user. Although the analysis of group data is beneficial, the process of using the mixer is an individual one in which various parameters of the signal are manipulated in order to make a *unique* and *individual* mix which is tailored specifically to the user.

### 5.2.3 Materials

**Mixer Application**

The central element in this study is the mixer application that has been specifically designed to allow CIUs to manipulate certain elements of music in order to create a mix that is personally tailored to their own listening needs. A detailed discussion of the design and functionality of this application is set forth in chapter 4.

**Equipment and Environment**

The study was conducted using the aforementioned mixer application running on a Macbook Pro (2.33GhZ Intel Core Duo). Audio was presented in free field by a pair of active Genelec 1029A monitors via an RME 'Fireface 400' interface in a small, quiet room.[2]

### 5.2.4 Procedure

In general, the user progresses to the next stage of the process by clicking a button labelled 'continue' at the bottom of most of the pages. Some pages are timed, however.

| Stage | Details | Duration (Approx.) |
|---|---|---|
| Welcome | Written information regarding the study, the approximate duration of involvement, and a basic guide to the program. See appendix D, figure D.1, for an image of this stage. | 30 sec. |
| User-Choice | Users must indicate whether they are CIUs or NH participants. Answering yes or no directs the participant to a different stage of the application. See appendix D, figure D.2, for an image of this stage. | 10 sec. |
| User-Details | General details including name, gender and age.<br>Additionally, CIUs are asked for information about their deafness and their history of CIs and hearing aids. See appendix D, figure D.3 (CIUs) and D.4 (NHs) for images of this stage. | 1 min. |
| Hearing-test (NH only) | NH subjects are given a very brief hearing test. See appendix D, figure D.5, for an image of this stage. | 2 min. |

[2]Some CI systems allow for direct injection (DI) into the processor by means of an audio connector cable, however, in the interests of consistency, the audio was presented to all participants (CI and NH) in free field so that each had access to the signal in the same way.

| Stage | Details | Duration (Approx.) |
|---|---|---|
| Operating Instructions | Participants are given four pages of detailed operating instructions that outline the function and operation of the controls and the participants role/objectives in the process. See appendix D, figure D.6, D.7, D.8 and D.9 for an image of this stage. | 5 min. |
| AV Demo | Participants are shown a video demonstration of the mixer being controlled with subtitled instructions. See appendix D, figure D.10 for an image of this stage. | 2 min. |
| Pre-Check | This checks that the participants are satisfied that they are fully aware and understand the instructions. Participants have the opportunity to press the continue button when they are ready to progress to the experiment or the option to return to the instructions. See appendix D, figure D.11 for an image of this stage. | 30 sec. |
| Working Trial | Participants are given two minutes to use the mixer as a trial, operating the controls in order to get used to the look and feel of the application that they will be using to complete the study. See appendix D, figure D.12 for an image of this stage. | 2 min. |

| Stage | Details | Duration (Approx.) |
|---|---|---|
| Main Mixer | Participants are free to use the mixer and data is collected based on the way that they choose to mix the music during the 5 minute (per piece) period. Only those settings that are in place upon completion of each mixing period are stored. Thus participants should ensure that they have completed a mix that they are happy with before the timer counts down to zero at which point the current mix will be saved, preventing any further editing of this mix for this music. Participants will be given the opportunity to rest between each mixing period but will be unable to halt the progress of the timer once the have pressed play. As this stage looks identical to the trial version, see appendix D, figure D.12 for an image of this stage. | 20 min. (4 x 5 min. sessions). |
| Mix Comparison | The user is presented with two different mixes of the same piece of music and asks them to make a comparison and select whether they preferred music A or B. Music A is the mix of one of the pieces created by the user in the previous section and music B is the mix of the source signals for the same piece. See appendix D, figure D.13 for an image of this stage. | 3 min. |
| Post-mixer Questionnaire | Users are asked to complete a post-study questionnaire which probes whether use of the mixer was beneficial/worthwhile and whether they would like to have the opportunity to do so again. See appendix D, figure D.14 for an image of this stage. | 3 min. |

| Stage | Details | Duration (Approx.) |
|---|---|---|
| Thanks and Completion | Informs the participant that they have completed the program and thanks them for their participation. See appendix D, figure D.15 for an image of this stage. | 30 sec. |

Study Progress

### 5.2.5 Stimuli

The previous chapter outlined the nature of the music used in conjunction with the mixer application from a technical point of view and discussed the musical construction of the multi-channel stimuli. The following provides details of the stimuli used in this study. The channels included for each piece of music are listed below with a brief outline of their musical and acoustic content in order to provide some ideas of the nature of the piece and each of it's constituent parts. Each track of the stimuli was performed live and on real (i.e. not synthesised) instruments, except the drum kit in each track, which was sequenced from *live* samples using Native Instruments' drum sampler/sequencer application, 'Battery 3'.

**Piece 1:**

This piece is in a pop style, in the key of G major and in 4/4 time, played at approximately 110BPM.

1. **Piano**: The piano is used primarily to provide harmonic information but also provides a degree of melodic/counter-melodic material. The RMS of this channel = -24.1dB.

2. **Lead Guitar**: The lead guitar is played with a lightly overdriven tone and is used to provide both counter-melodic information and, due to the way it is performed, provides some stylistic cues such as string bends and glissandi, for example. The RMS of this channel = -25dB.
3. **Drum Kit**: The drum kit provides the main rhythmic information. The RMS of this channel = -19.7dB
4. **Vocals (Female)**: The vocals (performed by a female in this case) provide the main melody and the songs lyrics. The RMS of this channel = -27.2dB.
5. **Bass**: The bass which mainly plays chord tones primarily provides harmonic information but does so rhythmically. The RMS of this channel = -27dB.
6. **Strummed Guitar**: The strummed guitar (acoustic, in this case) provides rhythmic and harmonic information. The RMS of this channel = -22.9dB.

**Piece 2:**

This piece is in a rock ballad style, in the key of A minor and in 6/8 time, played at approximately 70BPM.

1. **Bass**: The bass which mainly plays chord tones primarily provides harmonic information but does so rhythmically. The RMS of this channel = -26.6dB.
2. **Drum Kit**: The drum kit provides the main rhythmic information. The RMS of this channel = -27dB.
3. **Lead Guitar**: The lead guitar is played with an overdriven tone and is used to provide the main melodic information and, due to the way it is performed, provides some stylistic cues such as string bends and glissandi, for example. The RMS of this channel = -17.5dB.

4. **Piano**: The piano is used primarily to provide harmonic information but also provides a degree of melodic/counter-melodic material. The RMS of this channel = -25.7dB.

5. **Saxophone**: The saxophone is used to provide counter-melodic information and, as with the lead guitar, provides a degree of stylistic information. The RMS of this channel = -21dB.

6. **Strummed Guitar**: The strummed guitar (electric, in this case) provides rhythmic and harmonic information. The RMS of this channel = -23.5dB.

**Piece 3:**

This piece is in a blues style, in the key of E major and in 4/4 time, played at approximately 130BPM.

1. **Saxophone**: The saxophone is used to provide counter-melodic information and, as with the lead guitar, provides a degree of stylistic information. The RMS of this channel = -22dB.

2. **Piano**: The piano is used primarily to provide harmonic information but also provides a degree of melodic/counter-melodic material. The RMS of this channel = -25dB.

3. **Bass**: The bass which mainly plays chord tones primarily provides harmonic information but does so rhythmically. The RMS of this channel = -26.2dB.

4. **Lead Guitar**: The lead guitar is played with an overdriven tone and is used to provide the main melodic information and, due to the way it is performed, provides some stylistic cues such as string bends and glissandi, for example. The RMS of this channel = -14dB.

5. **Drum Kit**: The drum kit provides the main rhythmic information. The RMS of this channel = -17.7dB.

6. **Strummed Guitar**: The strummed guitar (electric, in this case) provides rhythmic and harmonic information. The RMS of this channel = -20.8dB.

**Piece 4:**

This piece is in a country/ballad style, in the key of E minor and in 4/4 time, played at approximately 90BPM.

1. **Bass**: The bass which mainly plays chord tones primarily provides harmonic information but does so rhythmically. The RMS of this channel = -14dB.

2. **Lead Guitar**: The lead guitar is played with an overdriven tone and is used to provide the main melodic information and, due to the way it is performed, provides some stylistic cues such as string bends and glissandi, for example. The RMS of this channel = -16.1dB.

3. **Drum Kit**: The drum kit provides the main rhythmic information. The RMS of this channel = -20dB.

4. **Vocals (Male)**: The vocals (performed by a male in this case) provide the main melody and the songs lyrics. The RMS of this channel = -24.9dB.

5. **Piano**: The piano is used primarily to provide harmonic information but also provides a degree of melodic/counter-melodic material. The RMS of this channel = -20.1dB.

6. **Strummed Guitar**: The strummed guitar (electric, in this case) provides rhythmic and harmonic information. The RMS of this channel = -13.5dB.

## 5.3 Data Analysis

Data output from the mixer application used in this study provides information to facilitate inferences about CIUs perception and experience of multi-channel music. By considering the relative prominence of signals in the mixes and valuable user feedback it is possible to comment on elements of music that are potentially problematic or, conversely, particularly well received. In doing this it is possible to observe how these elements can be altered in view of improving the musical experience, based on those steps taken by users when using the mixer application.

As the mixer was initially conceived of as an application that would allow individual users to tailor the sound of multi-channel music to suit them specifically, the interest was mainly in the individual differences of the users. This is important because the purpose of this application is to allow CIUs to tailor the mix of music to *their own* preferences/needs. From a practical perspective, information gained from considering data on an individual differences basis can inform CIUs and therapists, for example, of the type/styles of music that is most suitable to them as individuals. Considering the data in this way will allow us to gain information about the differences that exist between CIUs and the extent to which musical experiences and specific listening needs differ. From an exploratory/experimental point of view, the focus on group differences is also of great interest and provides valuable information relating to differences in preferences between CIU and NH participants.

### 5.3.1 Outline of Analyses Performed on Data

1. Comparison of Long Term Average Spectrum (LTAS) of average group mixes.

   Long-term average spectrum (LTAS) is an acoustic measurement that averages sound spectra over a relatively long period of time, rather than an instantaneous sample. In this case, the LTAS analysis was conducted using a filter bank consisting of twenty three 1/3 octave filters (99Hz - 16kHz) in SFS (Windows).[3] Figure 5.3 shows an example of a graph comparing the LTAS of two different signals and allows for the comparison of their spectra over the examined range. In graphs of this type presented in this chapter, error bars illustrate standard deviation by way of highlighting variability in the sample.

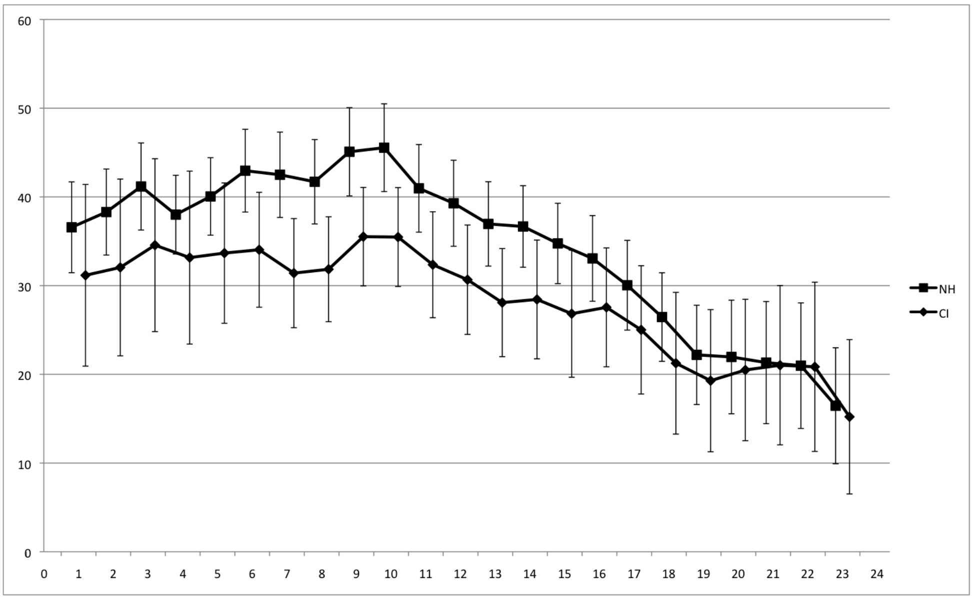



Figure 5.3: LTAS Example

This analysis is used to show individual differences amongst participants in order to highlight the variability or uniformity of results. An average mix (of each piece) was calculated for both groups, i.e. NH and CIU and was subjected to an LTAS analysis. Using a Mann-Whitney test, the difference between each group is tested for statistical significance, thus allowing us to discuss any differences which exist between the LTAS of each group's mean mix.

This essentially facilitates the analysis of the sound of music, and the differences between the group averages, from a spectral perspective. A further analysis of this

[3]SFS developed by University College London, 2008

information was also conducted for each EQ band (i.e. high, mid and low, as outlined above) thus providing more detailed information about differences which exist in specific areas of the spectrum. This was inspired by the many reports from CIUs (see chapters 2 and 3) of low-pitched musical sounds being preferable to high-pitched sounds.

2. Analyses of instruments included in mix.

   This analysis considers which instruments have been included in a user's mix. By analysing the stimuli in the manner outlined above, a knowledge of which instruments are included in the mix provides information on both the sounds chosen by the user and the musical elements contributed by these instruments. A mix containing only drums, bass and strummed guitar will have a different sound to one that contains piano, vocal and saxophone, for example, due to: (a) the sounds of these instruments both individually and collectively and; (b) the fact that they contribute different musical information (see information on construction of stimuli in chapter 4, and the outline of the stimuli above) to the mix. Therefore, the instruments included in a mix has a profound effect on the LTAS of the whole mix (above) thus, considering this information goes some way towards explaining differences or similarities in the results of the LTAS analysis.

   This analysis can be used to highlight individual differences amongst participants and can be used to make group comparisons (i.e. CIU vs NH).

3. Musical comparison of the mixes.

   Figure 5.4 shows a conflation (i.e. each individual signal on one graph) of the LTAS analysis of each element of a mix:

   From this, we can gain some descriptive information about the mix, namely: (a) the relative prominence of each of the signals (b) the musical quality of the mix, with

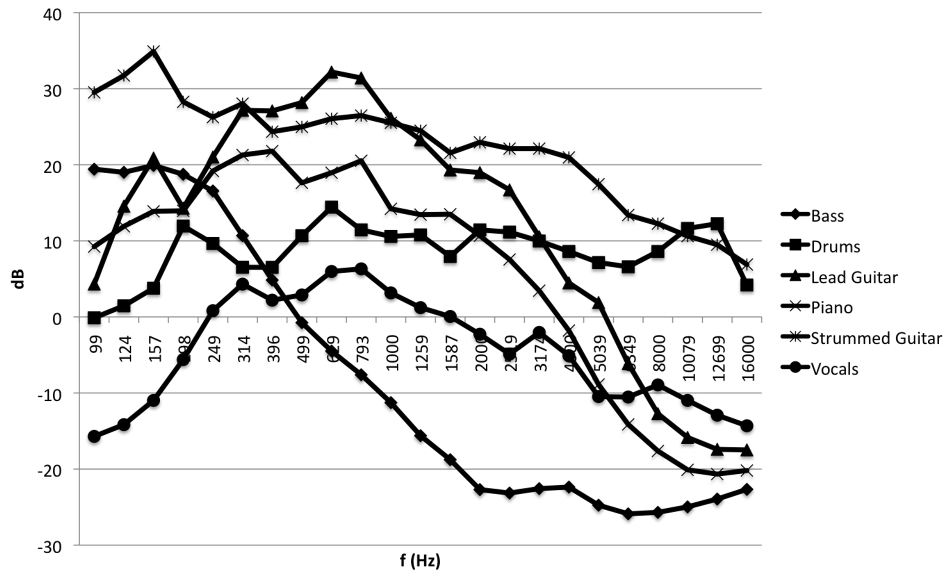



Figure 5.4: Conflated LTAS example

regard to the musical function of each channel/instrument. Such information will not involve statistical analysis but will provide important musical/descriptive/aesthetic information to compliment the statistical comparisons outlined above.

4. Comparative LTAS analysis of each channel.

This analysis/comparison was conducted for each of the six channels of audio, per mix and provides more detailed information about how the groups differ from each other with regard to the treatment of specific instruments within a mix. Comparisons are also made between each group and the source signal, thus providing details relating to the way that the users have manipulated the source signal to suit their preferences. This analysis was conducted on group data (averages) as a result of variability, particularly within the CIU group, with regard to the instruments included in the mix. As participants (CIUs particularly) did not include every instrument in each mix, results gathered from average group data contribute more to the analyses set forth below than a consideration of individual differences. As above, Mann-Whitney tests are used for statistical comparisons of the data.

# 5.4 Results

*NB All statistical analyses below were performed using Mann-Whitney tests, unless otherwise stated.*

## 5.4.1 Piece 1:

### Whole Mix

Figure 5.5 shows the average LTAS of each group's mix of piece 1.[4]

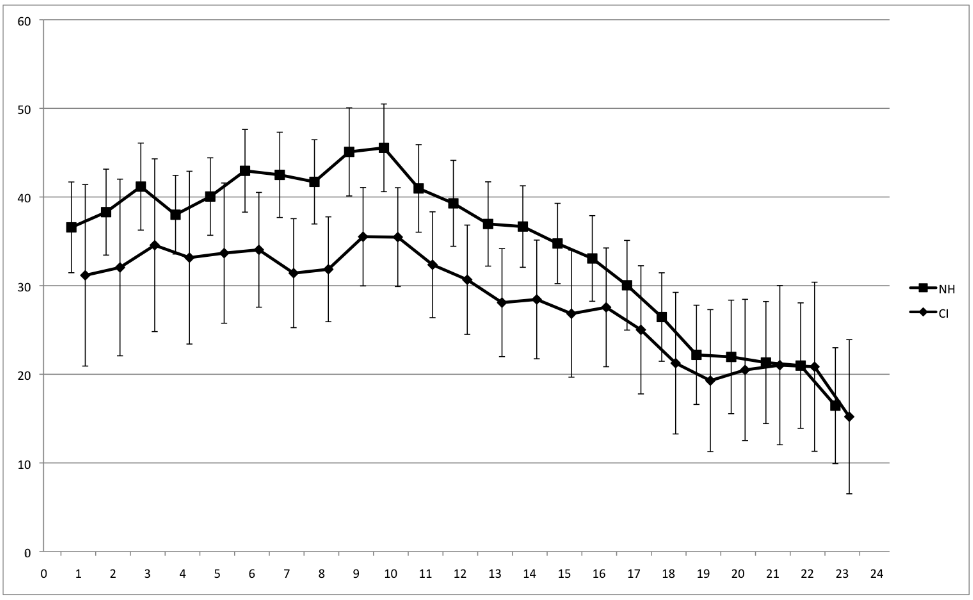



Figure 5.5: Comparison of group average LTAS for Piece 1

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p= | p= | p= | p= |
| CI vs. NH average | p<0.01 | p<0.01 | p<0.01 | p=ns |

Table 5.4: Statistical Comparison of group average LTAS for Piece 1

This data illustrates that the average mixes of the CIU group and the NH group,

[4]See appendix E for the LTAS of individual participants

respectively, are significantly different from each other across the examined spectrum; this is also the case in both the low and mid-bands but not in the high band. Generally speaking, we can see from the graph that the average mix of the CIU group shows less energy than that of the NH group across the whole examined spectrum and in each frequency band.

Tables 5.5 and 5.6 show the instruments which were included in each mix by individual participants in the CIU group and the NH group, respectively.

| User | Instruments Included |
|---|---|
| CIU 1 | Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| CUI 2 | Drum Kit, Vocals (Female), Bass |
| CIU 3 | Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| CIU 4 | Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| CIU 5 | Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| CIU 6 | Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| CIU 7 | Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| CIU 8 | Drum Kit, Vocals (Female), Bass, Strummed Guitar |

Table 5.5: Piece 1: CIU Individual Instrument Choices

| User | Instruments Included |
|---|---|
| NH1 | Piano, Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH2 | Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH3 | Piano, Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH4 | Piano, Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH5 | Piano, Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH6 | Piano, Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH7 | Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |
| NH8 | Piano, Lead Guitar, Drum Kit, Vocals (Female), Bass, Strummed Guitar |

Table 5.6: Piece 1: NH Individual Instrument Choices

Figures 5.6 and 5.7 show a conflation of the LTAS of each element of the average CIU and NH mixes respectively by way of visually representing the musical character of the mix of this piece. The conflation of LTAS analyses provides information about the prominence of the instruments across the spectrum and, if considered in conjunction with a knowledge of the nature of the stimuli (as presented above) provides valuable insight into the way in which the elements combine in order to form the whole mix.

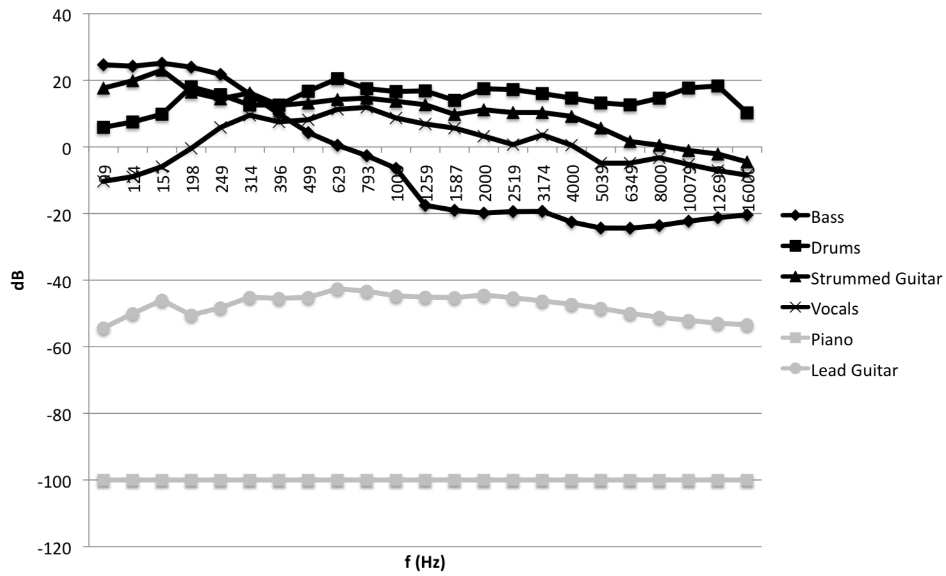



Figure 5.6: Piece 1 CIU Average Conflated LTAS

As can be seen from figure 5.6, the drums and strummed guitar are relatively prominent across the spectrum, particularly so below 6.5kHz (approximately). The bass is also prominent in the low band but, by it's nature, has very little energy in higher bands and the vocals show less energy across the majority of the spectrum than either the bass or the drums. From this we can tell that this is a mix with a strong rhythmic character and the most energy in the low and mid bands. The lead guitar channel in this average mix shows very little energy across the spectrum as it was not widely included by CIUs, the piano was not included by any CIU participant for this piece and thus shows no energy (i.e. silent).

Comparing this to figure 5.7 (below) we see that the conflated mix of each element in the NH average mix is considerably different to that of the the CIU group (above).

Figure 5.7 shows that the bass and drums are lower in the mix than the piano (which was not included in the average CIU mix) and the lead guitar (which was very low in the average CIU mix). This figure shows a more balanced mix and uses all the available

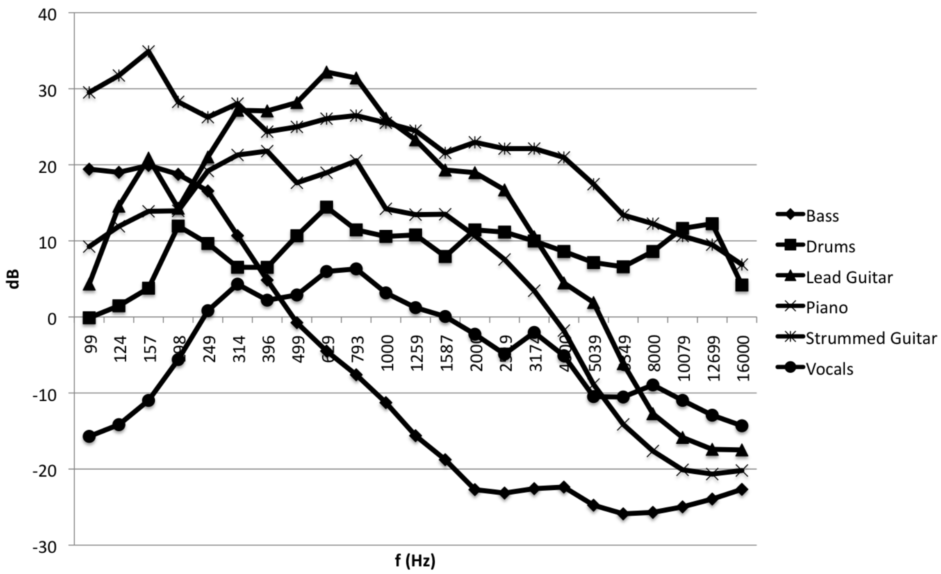
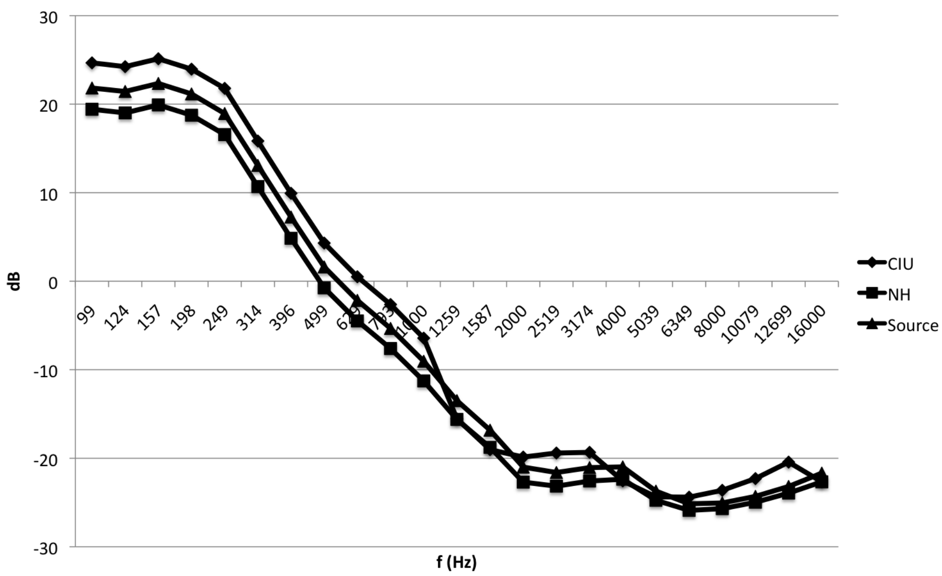



Figure 5.7: Piece 1 NH Average Conflated LTAS

source signals. This serves to highlight the more sparse and rhythmically focussed nature of the CI mix, by comparison.

### Individual Channels

### Bass

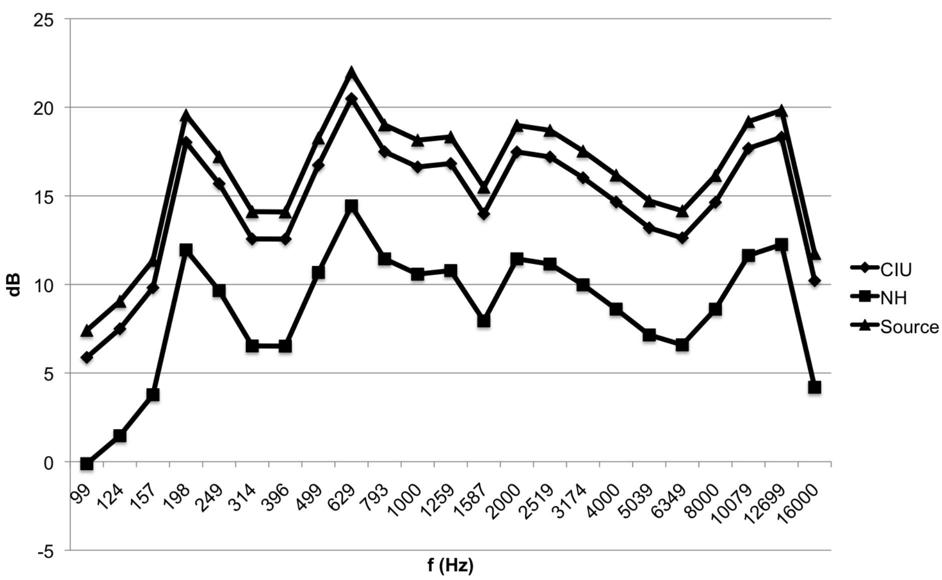


| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p= | p = | p = | p = |
| CI vs. NH averages | p=ns | p=ns | p=ns | p<0.05 |
| CI average vs. Source | p=ns | p=ns | p=ns | p=ns |
| NH average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.7: Comparisons of Average LTAS for the Bass Channel - Piece 1

Data for the bass channel shows that there is no significant difference between the source signal, the NH average mix and the CIU average treatment of this channel across the spectrum. This is also true for each of the frequency bands except for the the high-band where we notice a significant difference between the CIU and NH groups. A visual assessment of the graph data shows that the CIU line intersects and falls below both others around 1.2-1.3kHz, and that the opposite occurs around 5kHz.

**Drums**



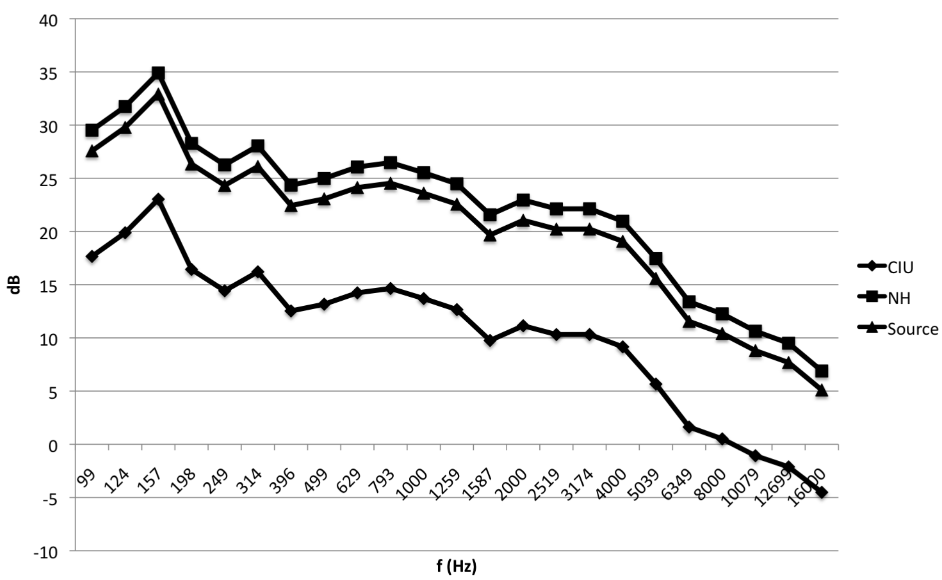

There was a significant difference between the average CIU and NH mixes for the drums channel across the whole spectrum and also in each of the three frequency bands. When

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | p = | p = | p = |
| CI vs. NH Averages | p<0.001 | p<0.05 | p<0.01 | p<0.001 |
| CI Average vs. Source | p=ns | p=ns | p<0.05 | p=ns |
| NH Average vs. Source | p<0.001 | p<0.01 | p<0.001 | p<0.001 |

Table 5.8: Comparisons of Average LTAS for the Drums Channel - Piece 1

comparing the average treatment of this CI channel with the source signal we see that there is no significant difference across the spectrum or in the high and low bands, however, the mid band shows a significant difference, albeit at a reasonable low level (approx p=0.05). The difference between the average NH mix of this channel and the source signal is highly significant (lower volume) across the entire observed spectrum and in each of the three frequency bands.

**Strummed Guitar**



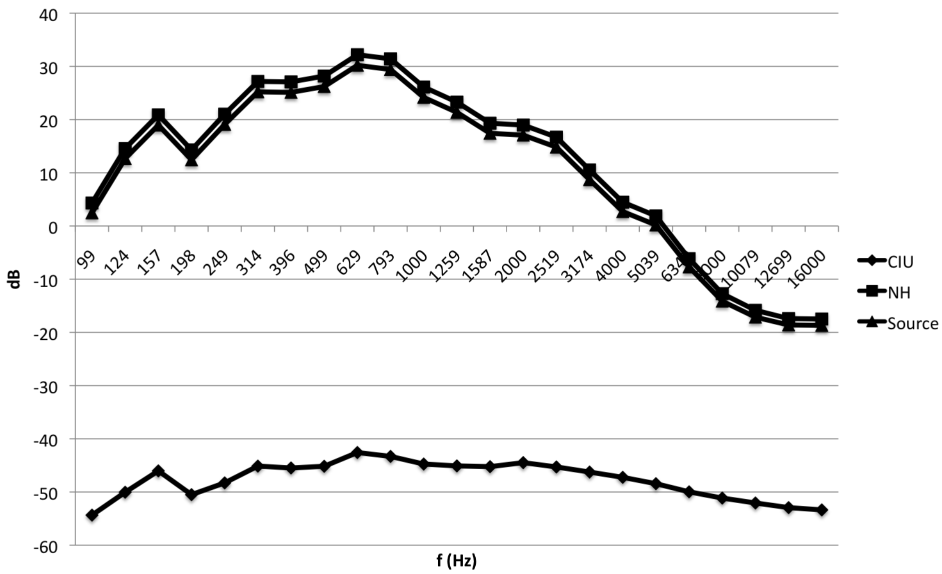

Data from the strummed guitar channel also illustrates that there is a significant difference between the average CIU and NH mixes for this channel across the whole

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.01 |
| NH Average vs. Source | p=ns | p=0.ns | p=ns | p=ns |

Table 5.9: Comparisons of Average LTAS for the Strummed Guitar Channel - Piece 1

spectrum and also in each of the three frequency bands. The difference between the average mix of the CIU group and the source signal shows that there is also a significant difference across the spectrum and in each of the three bands. The difference between the average NH mix of this channel and the source signal are not significantly different, however, the NH average is slightly higher in volume than the source signal.

**Lead Guitar**



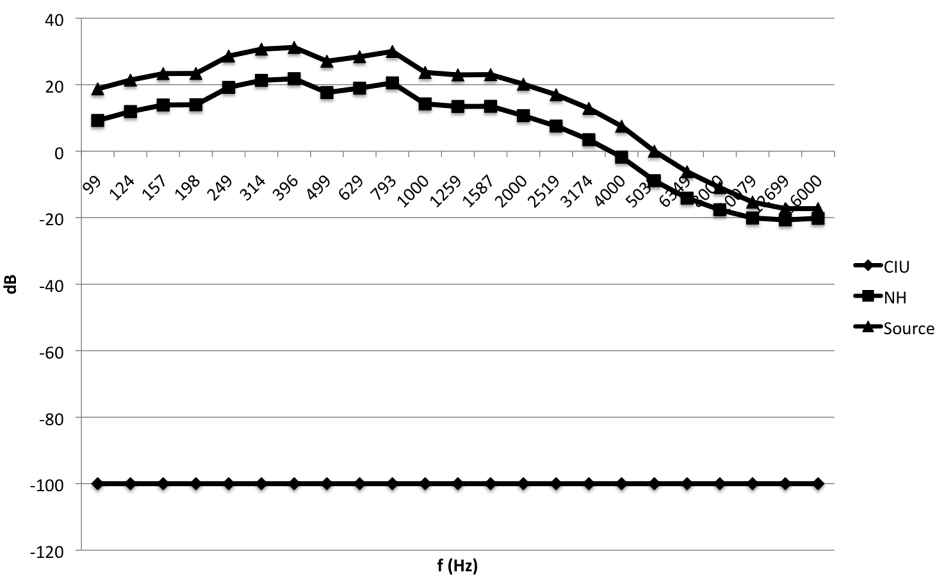

The lead guitar was not one of the audible instruments in the majority of the CIU participants' mixes and thus the average CIU mix of this channel shows very little energy across the spectrum. This comparison shows that the LTAS of the average CIU

|  | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.10: Comparisons of Average LTAS for the Lead Guitar Channel - Piece 1

mix differs significantly from the average NH mix and the LTAS of the source signal for this channel across the examined spectrum and in each of the frequency bands. The comparison of the average NH treatment of this channel and the LTAS of the source signals shows no significant difference in each of the frequency bands or across the entire examined spectrum.

**Piano**



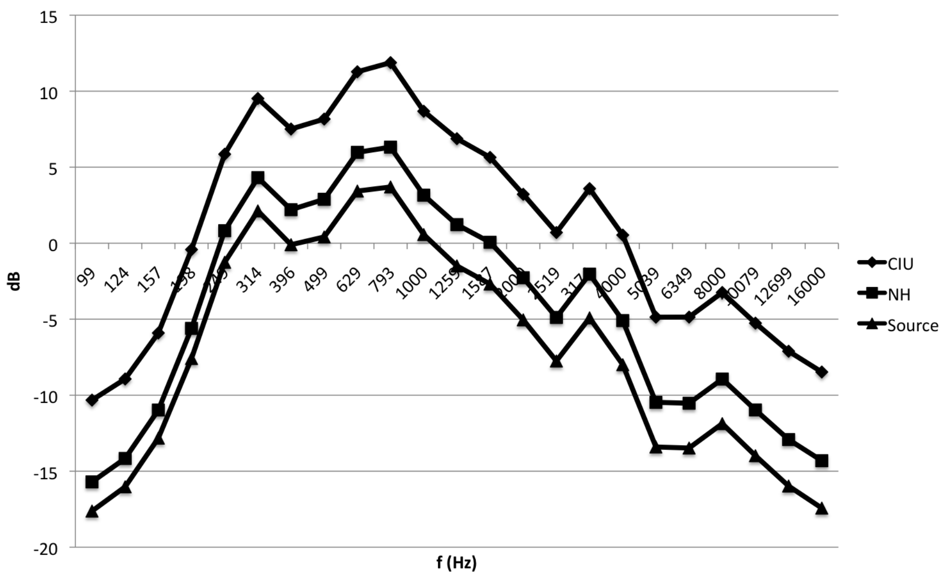

The piano was not included in any mixes by participants in the CIU group, hence the completely flat LTAS presented. This signals an entirely obvious difference between the average mix of CIU group this channel and both the NH group and the source signals.

|  | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| NH Average vs. Source | $p<0.01$ | $p<0.01$ | $p<0.01$ | p=NS |

Table 5.11: Comparisons of Average LTAS for the Piano Channel - Piece 1

The LTAS of the NH group's average mix of this channel and that of the source signal shows that there is a significant difference (lower in volume) between the channels and in the low and mid-bands but not, however, in the high-band.

**Vocals (Female)**




| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.01 | p=ns | p<0.05 | p<0.01 |
| CI Average vs. Source | p<0.001 | p=ns | p<0.01 | p<0.01 |
| NH Average vs. Source | p=ns | p=ns | p=ns | p<0.05 |

Table 5.12: Comparisons of Average LTAS for the Vocal (Female) Channel - Piece 1

The LTAS analyses of the vocal channel shows that there is a significant difference between the average NH mix and that of the CIU group across the spectrum and in the mid and high-bands, with the CIU showing the greater volume; the same applies to the difference between the CIU group and the source signal. When comparing the LTAS of the NH group with that of the source signals we see that there is no significant difference across the spectrum or in the low or mid-bands; a significant difference is noted in the high band, however, at which point the NH signal shows more energy than the source signal.

## 5.4.2 Piece 2

### Whole Mix

Figure 5.8 shows the average LTAS of each group's mix of piece 2.

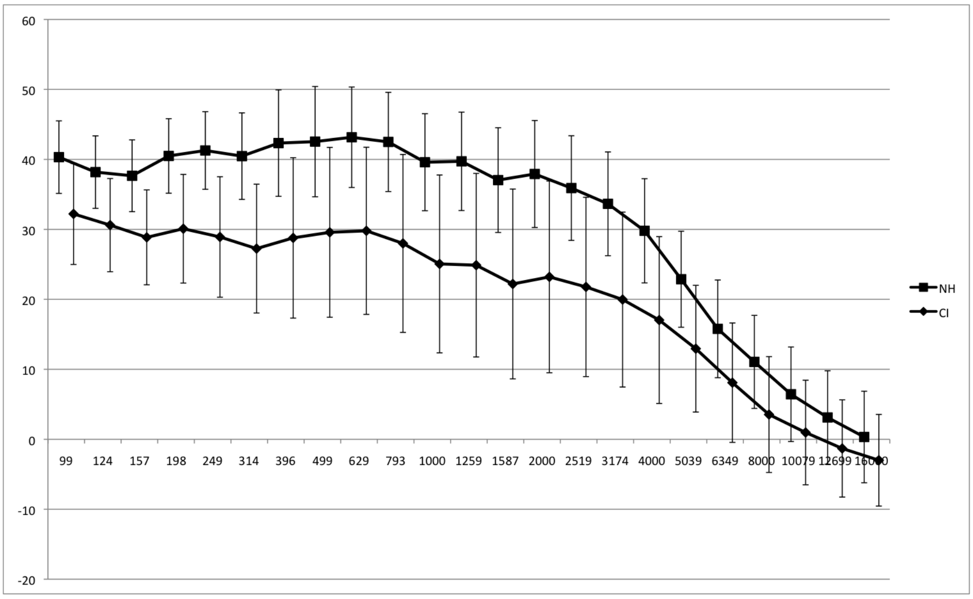



Figure 5.8: Comparison of Average LTAS for Piece 2

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p= | p= | p= | p= |
| CI vs. NH average | p<0.01 | p<0.01 | p<0.01 | p=ns |

Table 5.13: Statistical Comparison of group average LTAS for Piece 2

From the data above, we can see that the average mixes of the CIU group and the NH group, respectively, are significantly different from each other across the examined spectrum and in all three frequency bands. The graph shows that the average mix of the CIU group is significantly less loud than that of the NH group and that both the NH and CIU average mixes are significantly lower in volume than the source signal across the whole examined spectrum and in each frequency band.

Tables 5.14 and 5.15 show the instruments that were included in each mix by individual participants in the CIU and NH groups, respectively.

| User | Instruments Included |
|---|---|
| CIU 1 | Strummed Guitar, Saxophone, Piano, Lead Guitar, Drums, Bass |
| CUI 2 | Strummed Guitar, Drums, Bass |
| CIU 3 | Strummed Guitar, Drums, Bass |
| CIU 4 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass |
| CIU 5 | Strummed Guitar, Saxophone, Lead Guitar, Drums |
| CIU 6 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass |
| CIU 7 | Strummed Guitar, Saxophone, Lead Guitar, Drums |
| CIU 8 | Strummed Guitar, Drums, Bass |

Table 5.14: Piece 2: CIUs Individual Instrument Choices

| | |
|---|---|
| NH1 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |
| NH2 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |
| NH3 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |
| NH4 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |
| NH5 | Strummed Guitar, Saxophone, Drums, Bass, Piano |
| NH6 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |
| NH7 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |
| NH8 | Strummed Guitar, Saxophone, Lead Guitar, Drums, Bass, Piano |

Table 5.15: Piece 2: NH Individual Instrument Choices

The following figures show a conflation of the LTAS of each element of the average CIU and NH mixes respectively (as above) by way of visually representing the musical character of the mix of this piece.

As figure 5.9 shows, the bass and drums in this mix are more prominent than the strummed guitar across the vast majority of the spectrum. Again this highlights the fact that the musical character of the average mix of the CIU is one that has a strong rhythmic character and a considerable amount of energy in the low band. It should be noted that in this mix the lead guitar, which provides the main melodic information for this piece, has not been included. This is further evidence to suggest that the CIU group favour rhythmic information and low pitched musical sounds, even to the exclusion of material which may otherwise be considered as central or imperative to the collective musical

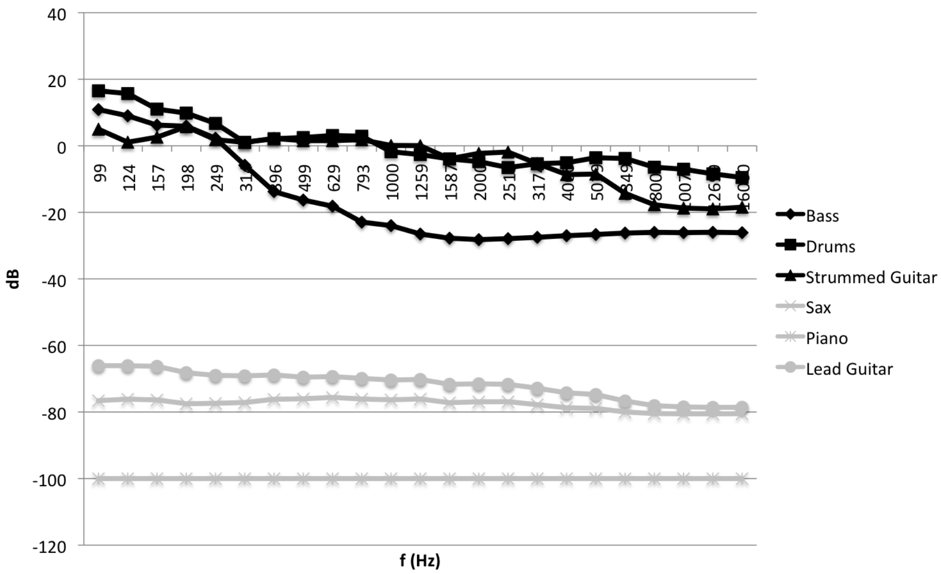



Figure 5.9: Piece 2 CIU Average Conflated LTAS

information provided by this piece.

This is in contrast to 5.10 which, as with piece 1, shows a more balanced mix of the available channels and shows the piano to be considerably higher in the mix than a lot of the other instruments across a large proportion of the spectrum. The same applies to the lead guitar which, as noted above, was not included in the average mix of the CIU group. Interestingly, in this case the drums, bass and strummed guitar, (i.e. the elements included in the CIU group's average mix) show the least energy across the spectrum, suggesting that these elements are foundations that the rest of the musical information is 'built' upon.

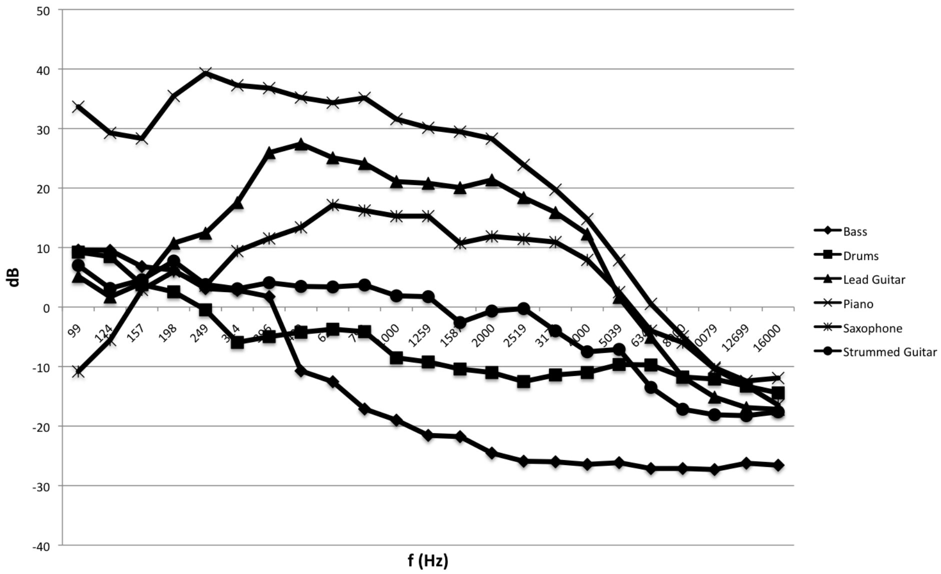
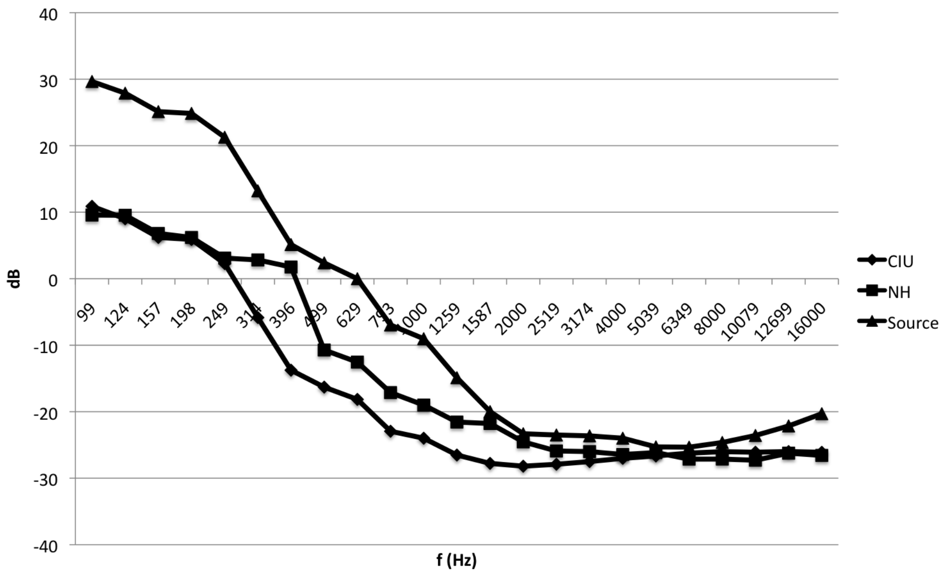



Figure 5.10: Piece 2 NH Average Conflated LTAS

### Individual Channels

### Bass




When comparing the average treatment of this channel by the CIU group and the NH group we observe that there is no significant difference across the spectrum of in the low and high bands. Results show that both the average mix of this channel by the NH group

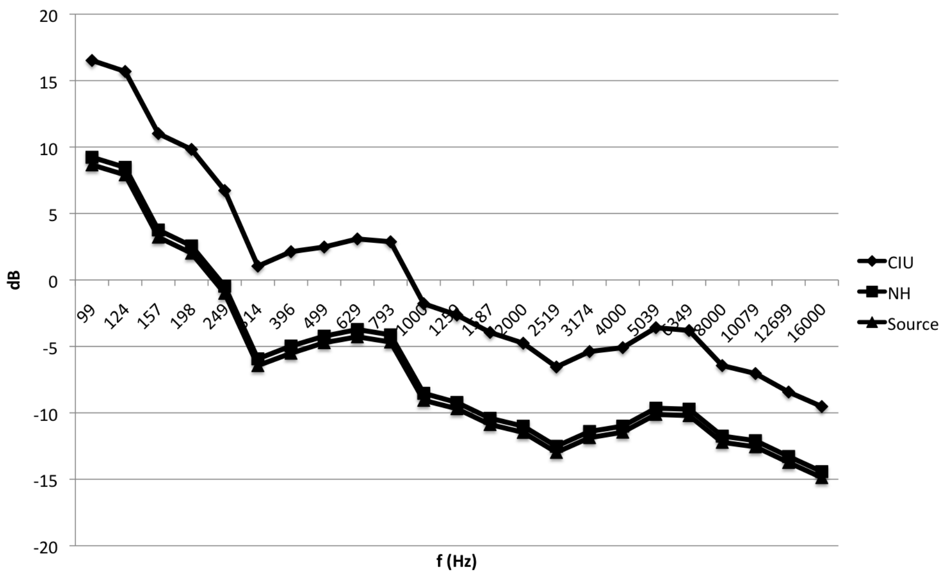
| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | p = | p = | p = |
| CI vs. NH Averages | p=ns | p<0.05 | p=ns | p<0.001 |
| CI Average vs. Source | p=ns | p=ns | p<0.05 | p=ns |
| NH Average vs. Source | p<0.05 | p<0.05 | p<0.001 | p<0.001 |

Table 5.16: Comparisons of Average LTAS for the Bass Channel - Piece 2

differs significantly from the source across the spectrum and in the low and high bands. The average treatment of this channel by the CIU group does not differ significantly from the source across the entire spectrum, however, there is a significant difference noted in the mid band.

The bass channel shows that there is no significant difference between the source signal, the NH average mix and the CIU average treatment of this channel across the spectrum. This is also true for each of the frequency bands except for the the high-band where we notice a significant difference between the CIU and NH groups. A visual assessment of the graph data shows that the CIU line intersects and falls below both others around 1.2-1.3kHz, and that the opposite occurs around 5kHz.

**Drums**

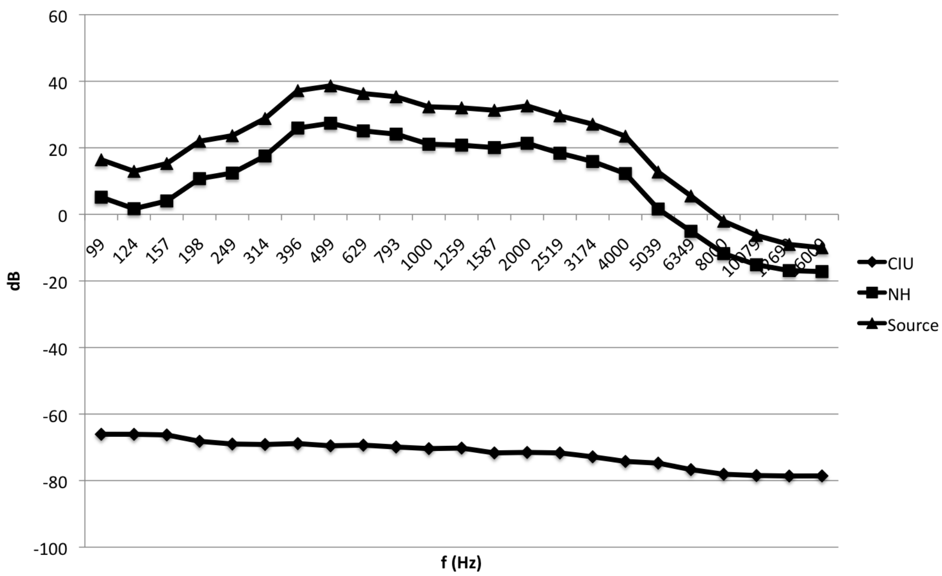



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | p = | p = | p = |
| CI vs. NH Averages | p<0.001 | p<0.05 | p<0.01 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.05 | p<0.01 | p<0.001 |
| NH Average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.17: Comparisons of Average LTAS for the Drums Channel - Piece 2

The data from the drums channel shows that there is a significant difference between the average CIU and NH mixes for this channel across the whole spectrum and also in each of the three frequency bands. When comparing the average treatment of this CI channel with the source signal we see that there is a significant difference across the spectrum and also in each of the three bands. The difference between the average NH mix of this channel and the source signal is not significant and the LTAS of the signals are almost identical.

**Lead Guitar**

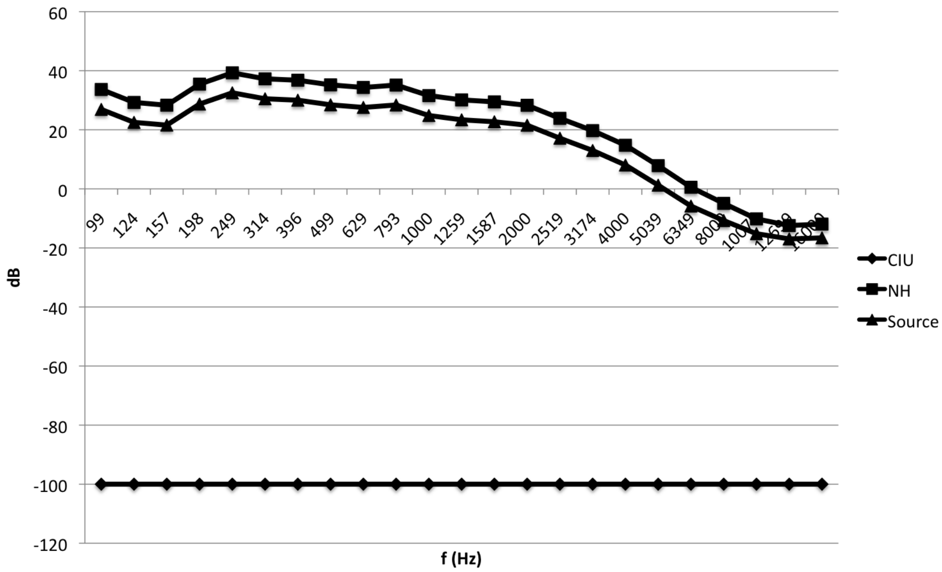



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | p = | p = | p = |
| NH Average vs. Source | p<0.01 | p<0.05 | p<0.001 | p=ns |

Table 5.18: Comparisons of Average LTAS for the Lead Guitar Channel - Piece 2

As the lead guitar was not included in the majority of mixes by participants in the CIU group, this average treatment of this channel by the CIU group shows very little energy across the examined spectrum. When comparing the LTAS of the average treatment of this channel by the CIU group to that of the NH group we notice a significant difference across the LTAS and in each of the three frequency bands; this is also the case when the CIU group's LTAS for this channel is compared to that of the source signals. Comparing the LTAS of the average treatment of this channel by the NH group to that of the source signal shows that there is a significant difference across the spectrum and also in each of the three frequency bands.

## Piano

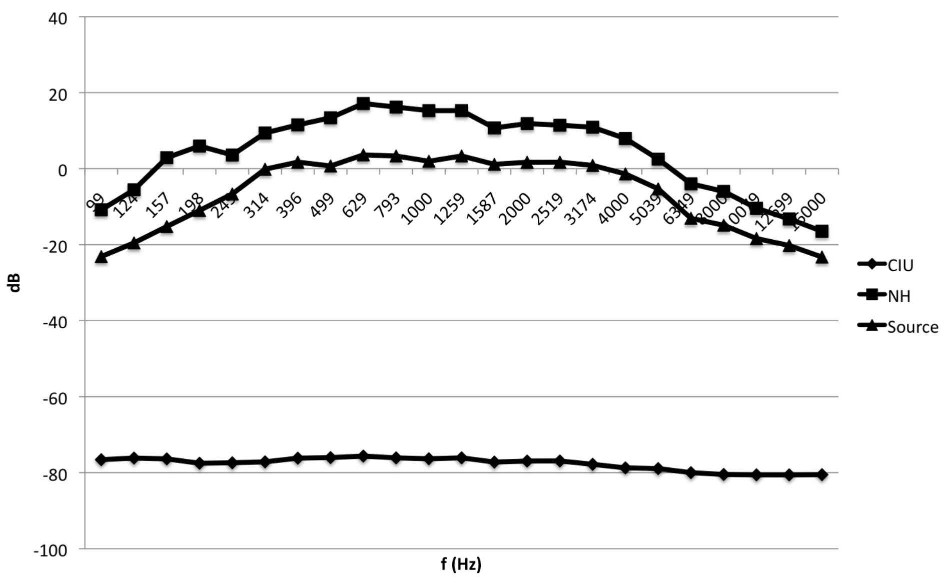



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p<0.05 | p<0.01 | p<0.01 | p=ns |

Table 5.19: Comparisons of Average LTAS for the Piano Channel - Piece 2

The piano was only included by one participant in the CIU group and thus the average treatment of this channel shows almost no energy across the spectrum. Therefore, when comparing the CIU groups average treatment to that of the NH group we notice a significant difference across the examined spectrum and in each of the frequency bands; this is also the case when comparing the LTAS of the average treatment of this channel by the CIU group to the LTAS of the source signals. The difference between the LTAS of the NH group's average mix and that of the source signal is statistically significant across the whole spectrum (NH higher in volume) and in the low and mid-bands.

**Saxophone**

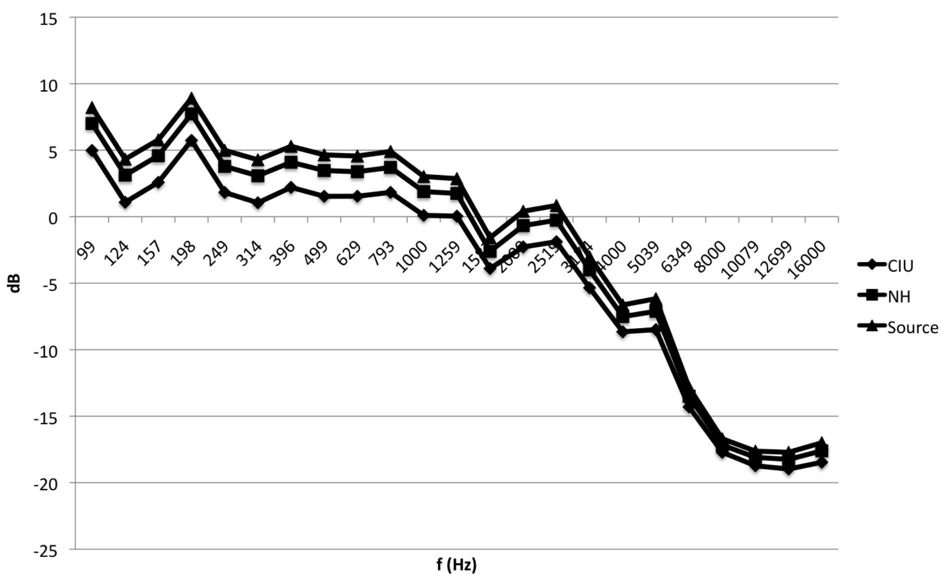



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p= | p= | p= | p= |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p=ns |

Table 5.20: Comparisons of Average LTAS for the Saxophone Channel - Piece 2

Although the saxophone channel was included by 5 of the 8 CIU participants for this piece, the average mix of the CIU group shows very little energy across the spectrum. When comparing the LTAS of the CIU groups average mix of this channel to that of the NH group and the source signals, we notice a significant difference across the examined spectrum and in each of the three frequency bands. A comparison between the LTAS of the average treatment of this channel by the NH group and the LTAS of the source signals shows that the NH group's LTAS is significantly different across the spectrum (higher in volume) and in the low and mid bands.

**Strummed Guitar**




| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p= | p= | p= | p= |
| CI vs. NH Averages | p=ns | p<0.05 | p=ns | p=ns |
| CI Average vs. Source | p<0.05 | p<0.01 | p<0.05 | p=ns |
| NH Average vs. Source | p=ns | p<0.05 | p=ns | p=ns |

Table 5.21: Comparisons of Average LTAS for the Strummed Guitar Channel - Piece 2

A comparison of the LTAS of the CIU and NH group's average mix shows that there is no significant difference across the spectrum or in the mid and high-bands. Comparing the LTAS of the CI group's average mix with that of the source signal we see that there is a significant difference across the spectrum and in the low and high-bands. When comparing the LTAS of the NH group's average mix to that of the source signal there is no significant difference across the spectrum or in the mid or high-bands.

### 5.4.3 Piece 3

**Whole Mix**

Figure 5.11 shows the average LTAS of each group's mix of piece 3.

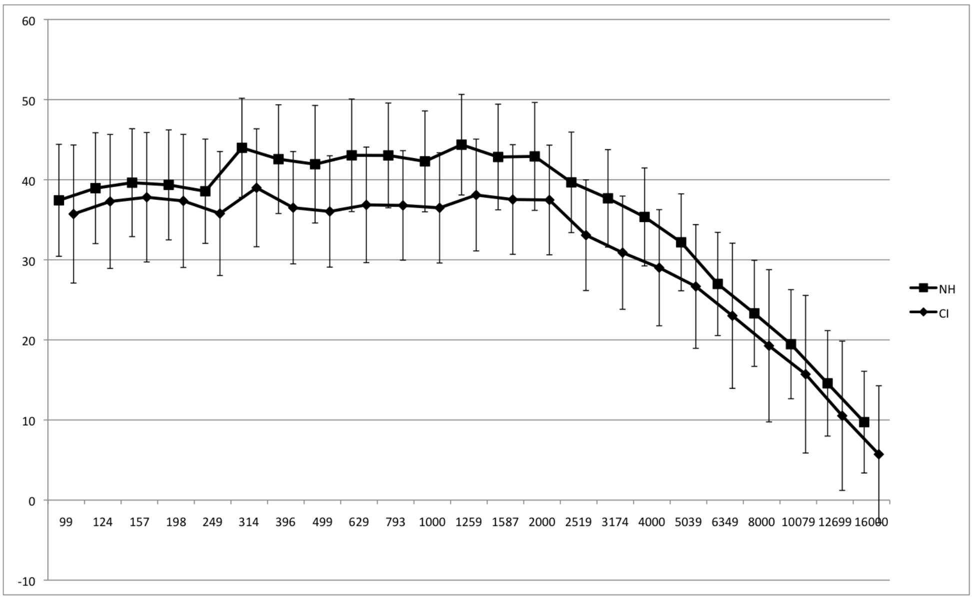



Figure 5.11: Comparison of Average LTAS for Piece 3

| Comparison | p = | | | |
|---|---|---|---|---|
| CI vs. NH Averages | p<0.05 | p<0.01 | p<0.01 | p=ns |

Table 5.22: LTAS of Average Mixes for Piece 3

In this case we can see, again, that the average mixes of the CIU group and the NH group, respectively, are significantly different from each other across the examined spectrum; this is also the case in both the low and mid-bands but not in the high band. The data shows that the average mix of the CIU group is less loud than that of the NH group in both the low and mid-bands but in the high band, the lines intersect showing that the CIU group's average mix has more energy in this area. Again, both the NH and CIU average mixes are significantly lower in volume than the source signal across the whole examined spectrum and in each frequency band.

Tables 5.23 and 5.24 show the instruments that were included in each mix by individual participants in the CIU and NH groups, respectively.

| User | Instruments Included |
|---|---|
| CIU 1 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| CUI 2 | Drums, Lead Guitar |
| CIU 3 | Strummed Guitar, Drums, Lead Guitar, Bass |
| CIU 4 | Strummed Guitar, Drums, Lead Guitar, Bass, Saxophone |
| CIU 5 | Strummed Guitar, Drums, Lead Guitar, Bass |
| CIU 6 | Strummed Guitar, Drums, Lead Guitar, Bass, Saxophone |
| CIU 7 | Strummed Guitar, Drums, Lead Guitar, Bass, Saxophone |
| CIU 8 | Strummed Guitar, Drums, Bass |

Table 5.23: Piece 3: CIUs Individual Instrument Choices

| User | Instruments Included |
|---|---|
| NH1 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH2 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH3 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH4 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH5 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH6 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH7 | Strummed Guitar, Drums, Lead Guitar, Bass, Piano, Saxophone |
| NH8 | Strummed Guitar, Drums, Lead Guitar, Bass, Saxophone |

Table 5.24: Piece 3: NH Individual Instrument Choices

Figures 5.12 and 5.13 show a conflation of the LTAS of each element of the average CIU and NH mixes respectively (as above) by way of visually representing the musical character of the mix of this piece.

Figure 5.12 shows that in the low band the drums and bass are most prominent and the drums show more energy than the other channels across the majority of the spectrum. In the mid band both the lead guitar and the strummed guitar are also relatively prominent. Again, as with the average mixes of the CI group for pieces 1 and 2, above, this figure shows a mix which has a strong rhythmic character with the melodic information also included but in such a way that those signals which provide the most obvious rhythmic information remain the most prominent.

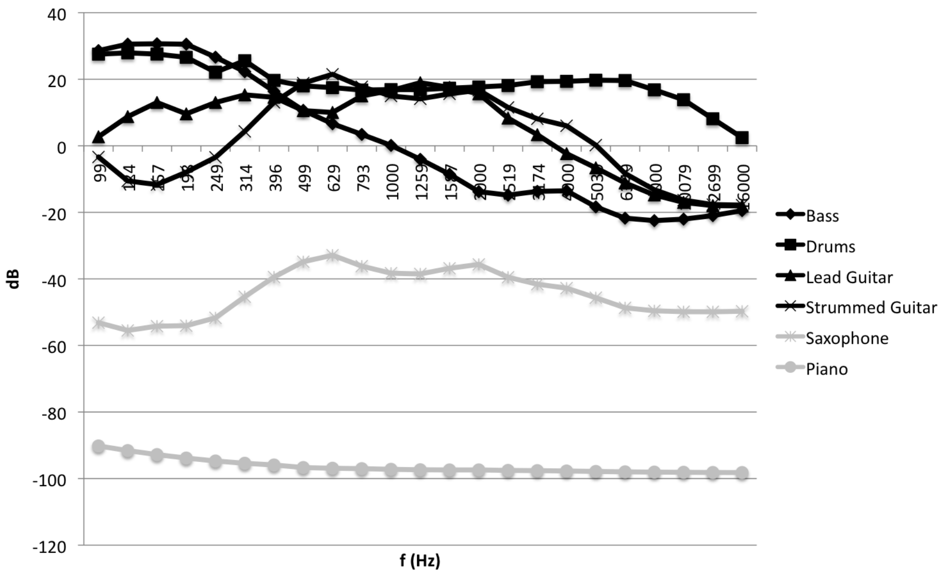



Figure 5.12: Piece 3 CIU Average Conflated LTAS

Figure 5.13 shows that instruments such as the piano and the saxophone, which were not included in the average mix of the CIU group, show more energy in this mix than the drums and bass, for a large proportion of the mix. Although this mix also seems to show a strong musical character, other musical elements such as melody and harmony are also obviously quite prominent as a result of the musical contributions of such instruments as the piano, saxophone and lead guitar, for example. This is something which seems to be in contrast to the average mixes of the CIU group who generally seem to favour rhythmic information and the sound of the bass.

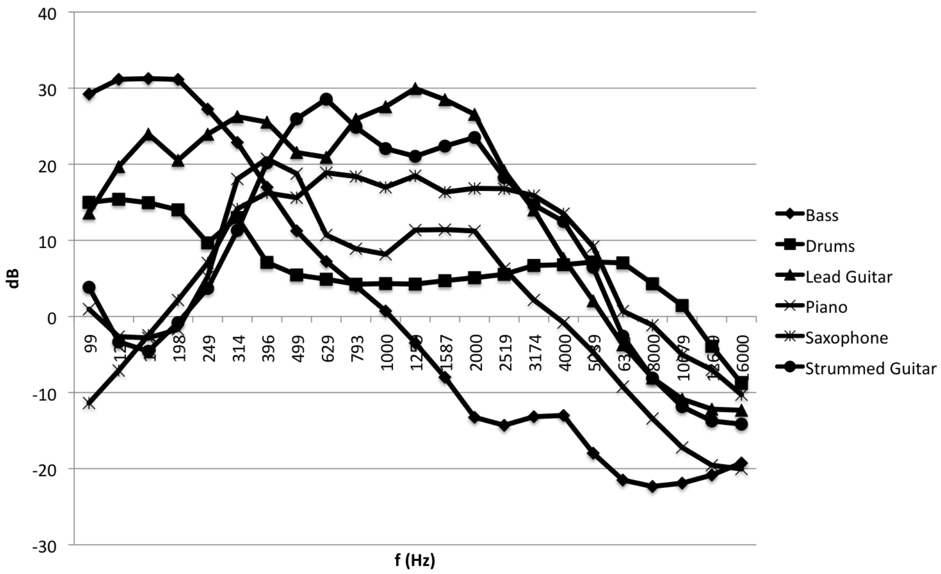
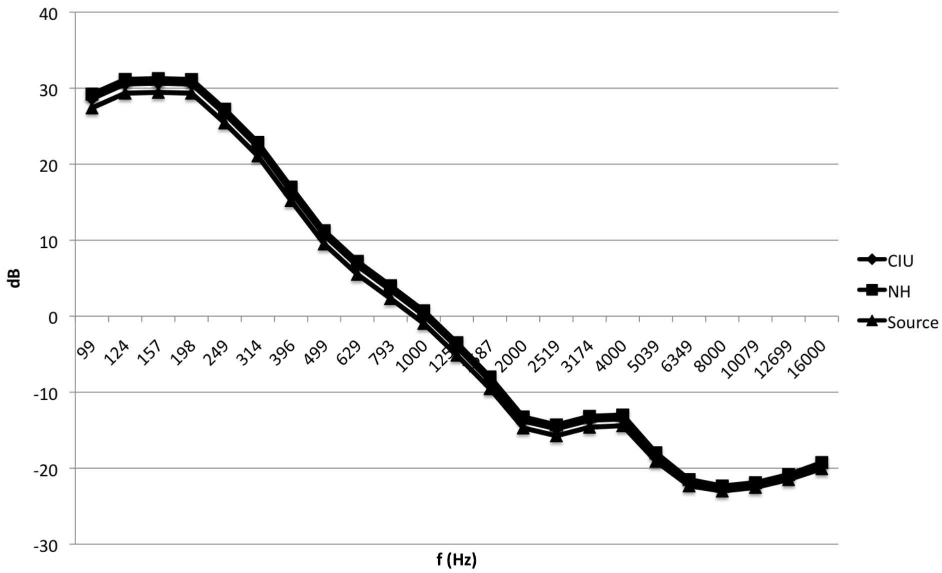



Figure 5.13: Piece 3 NH Average Conflated LTAS

### Individual Channels

### Bass

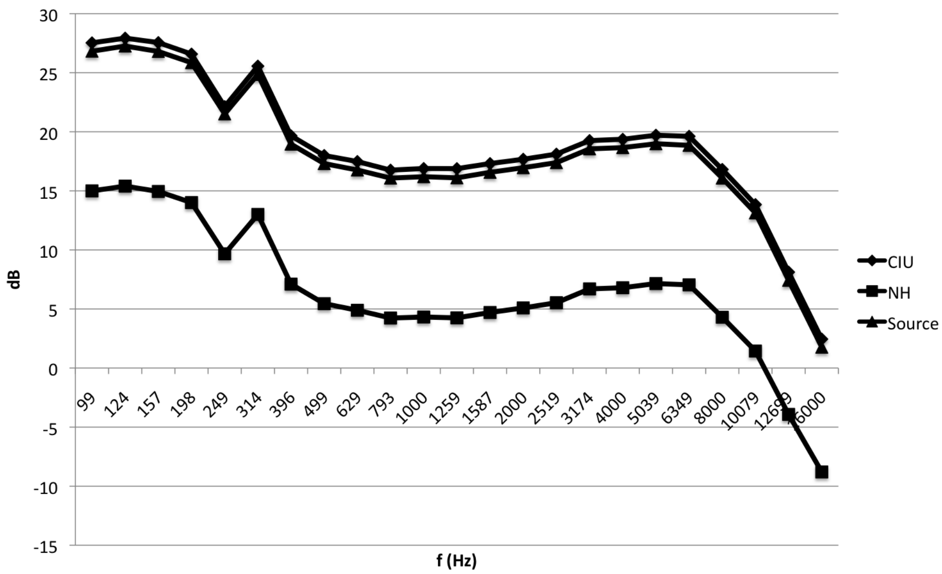



Data from the bass channel shows that the LTAS of the CIU group, the NH group and the source signal are almost identical. There is no significant difference between any of the signals across the spectrum or in any of the frequency-bands.

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p=ns | p=ns | p=ns | p=ns |
| CI Average vs. Source | p=ns | p=ns | p=ns | p=ns |
| NH Average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.25: Comparisons of Average LTAS for the Bass Channel - Piece 3

**Drums**

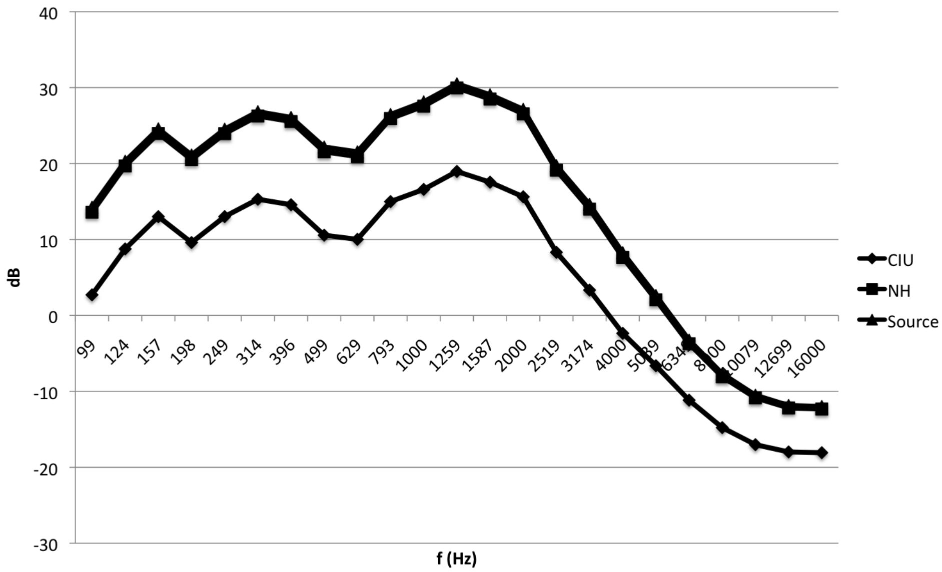



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p=ns | p<0.05 | p<0.05 | p=ns |
| NH Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.001 |

Table 5.26: Comparisons of Average LTAS for the Drums Channel - Piece 3

When comparing the LTAS of the CIU group's average mix for the drums with that of the NH group we see that there is a significant difference across the spectrum and in each of the three frequency bands. Comparing the CIU group's mix to that of the source signal shows that there is no significant difference across the spectrum but that there is in the low and mid-bands. A comparison between the NH group's average mix and the source signal shows that there is a significant difference such that the NH group is lower in volume across the spectrum.

**Lead Guitar**

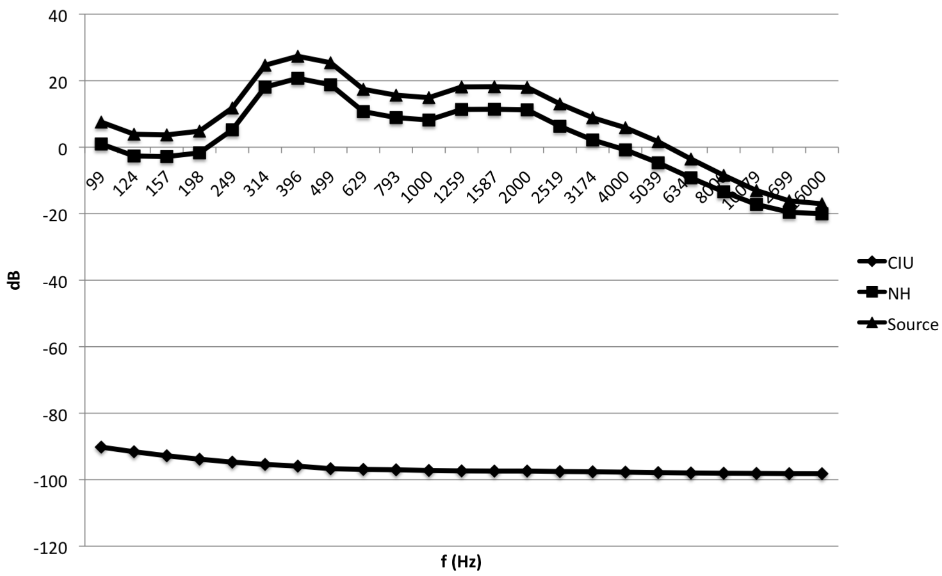



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | p = | p = | p = |
| CI vs. NH Averages | p<0.01 | p<0.001 | p<0.001 | p=ns |
| CI Average vs. Source | p<0.01 | p<0.001 | p<0.001 | p=ns |
| NH Average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.27: Comparisons of Average LTAS for the Lead Guitar Channel - Piece 3

A comparison of the LTAS of the CIU's average mix of the lead guitar channel and that of the NH group shows that there is a significant difference across the spectrum and in the low and mid-bands. The NH group's signal for this channel is almost identical to that of the source signal and there is no significant difference across the spectrum or in any of the frequency-bands.

**Piano**

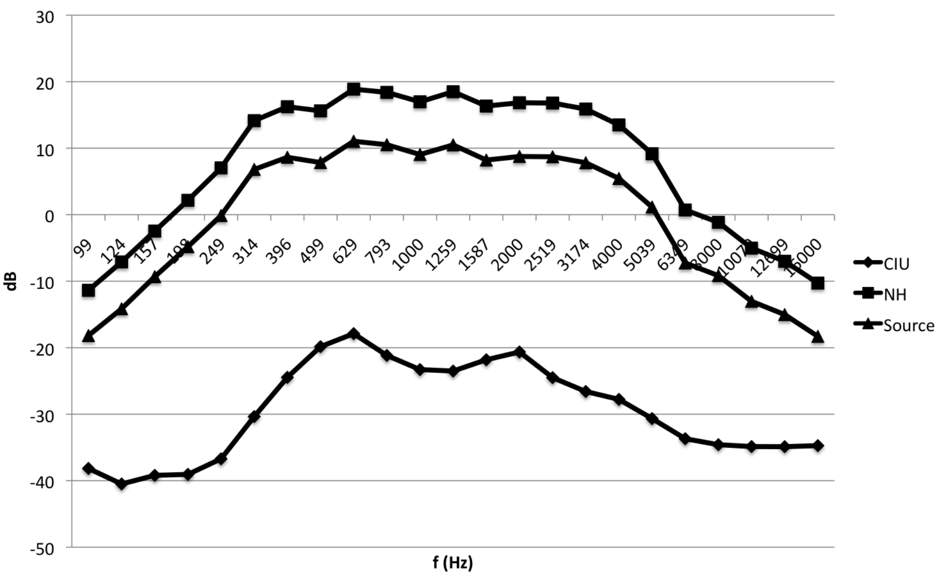



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p<0.05 | p=ns | p<0.001 | p=ns |

Table 5.28: Comparisons of Average LTAS for the Piano Channel - Piece 3

The piano was only included in one of the CIU participant's mixes, hence the low energy across the spectrum. When comparing the LTAS of the CIU groups average mix of this channel and that of the NH group we observe a significant difference across the whole examined spectrum and in each of the three bands; this is also the case when comparing the CIU group to the LTAS of the source signal for this channel. A comparison between the LTAS of the NH group's average treatment of this channel and the source signal shows a significant difference across the spectrum but not in the low or high-bands.

**Saxophone**

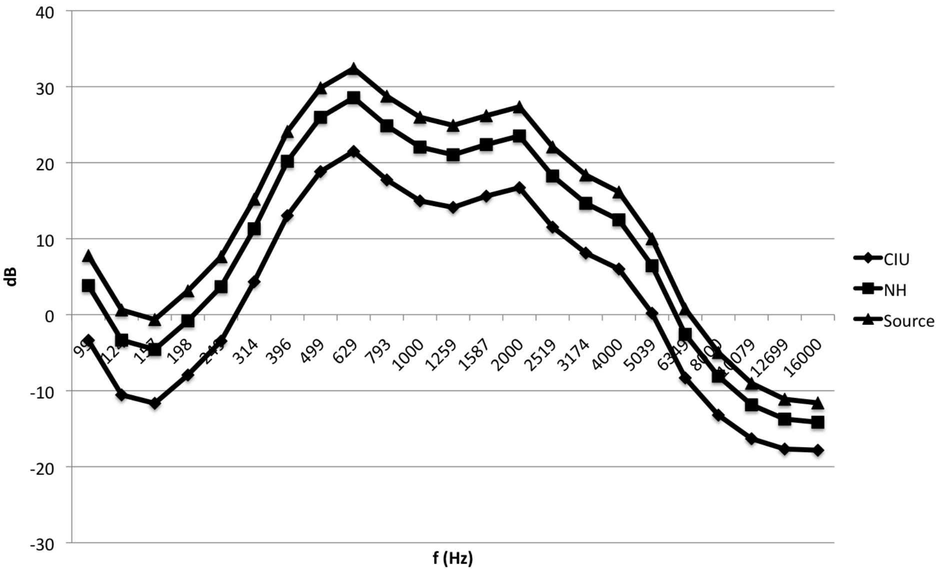



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p= | p= | p= | p= |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | p<0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p<0.01 | p=ns | p<0.001 | p=ns |

Table 5.29: Comparisons of Average LTAS for the Saxophone Channel - Piece 3

The saxophone was included in the mix of half of the participants in the CIU group, hence the comparatively low energy across the spectrum in the average mix of this group. A comparison of the LTAS of this signal with that of the NH group's average treatment of this channel shows a significant difference across the examined spectrum and in each of the frequency bands. This is also true for the comparison between that of the CIU group and the source signal for this channel. Comparing the LTAS of the NH group's average mix with that of the source signal shows that there is a significant difference across the spectrum but not in the low or high-bands.

**Strummed Guitar**




| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p=ns | p=ns | p<0.01 | p=ns |
| CI Average vs. Source | p<0.01 | p<0.05 | p<0.001 | p=ns |
| NH Average vs. Source | p=0.ns | p=ns | p<0.05 | p=ns |

Table 5.30: Comparisons of Average LTAS for the Strummed Guitar Channel - Piece 3

Data from the strummed guitar channel shows that the LTAS of the CIU group's average mix and that of the NH group's average are not significantly different across the spectrum or in the low or high-bands. Comparing the CIU group's results to those of the source signal we see that there is a significant difference across the whole spectrum, but not in the low or high-bands. When comparing the LTAS of the NH group's average treatment of this channel to that of the source signal we notice that there is no significant difference across the spectrum or in each of the frequency bands.

### 5.4.4 Piece 4

#### Whole Mix

Figure 5.14 shows the average LTAS of each group's mix of piece 4.

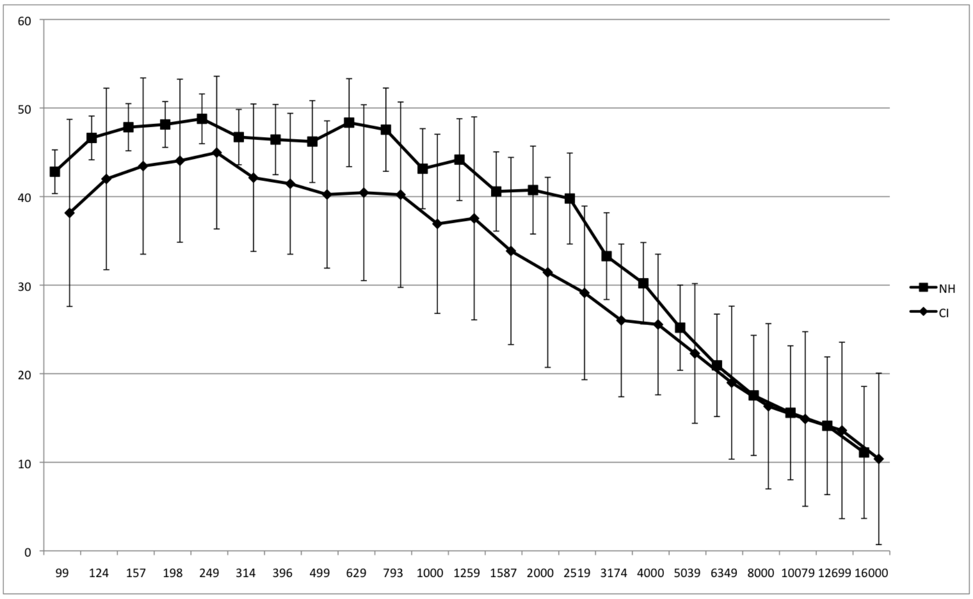



Figure 5.14: Comparison of Average LTAS for Piece 4

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p<0.001 | p<0.001 | p<0.001 | p=ns |

Table 5.31: LTAS of Average Mixes for Piece 4

For this stimulus, the data also shows that the average mixes of the CIU group and the NH group differ significantly from one and other across the examined spectrum and in both the low and mid-bands but not in the high band. We can see from the graph that the average mix of the CIU group is less loud than that of the NH group and that both the NH and CIU average mixes are significantly lower in volume than the source signal across the whole examined spectrum and in each frequency band.

Tables 5.32 and 5.33 show the instruments that were included in each mix by individual participants in the CIU and NH groups, respectively.

| User | Instruments Included |
|---|---|
| CIU 1 | Piano, Vocal, Drums, Lead Guitar, Bass |
| CUI 2 | Vocal, Bass |
| CIU 3 | Strummed Guitar, Vocal, Drums, Lead Guitar, Bass |
| CIU 4 | Strummed Guitar, Vocal, Drums, Bass |
| CIU 5 | Vocal, Drums, Bass |
| CIU 6 | Strummed Guitar, Vocal, Drums, Lead Guitar, Bass |
| CIU 7 | Strummed Guitar, Vocal, Drums |
| CIU 8 | Strummed Guitar, Vocal, Drums, Bass |

Table 5.32: Piece 4: Individual Instrument Choices

| User | Instruments Included |
|---|---|
| NH1 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH2 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH3 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH4 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH5 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH6 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH7 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |
| NH8 | Strummed Guitar, Piano, Vocal, Drums, Lead Guitar, Bass |

Table 5.33: Piece 4: NHs Individual Instrument Choices

The following figures show a conflation of the LTAS of each element of the average CIU and NH mixes (as above) respectively by way of visually representing the musical character of the mix of this piece.

Figure 5.15 shows results similar to each piece outlined above such that the drums and strummed guitar are relatively prominent across the spectrum and that the bass shows a great deal more energy than any other channel in the low band. The vocal channel which is responsible for providing the main melodic information, in addition to the lyrics, is also fairly prominent in the low/mid-bands (presumably as a result of being a male singer with a low-pitched voice). again, with regard to the musical character, we can tell that this is a mix that has strong/prominent rhythmic information and one that favours

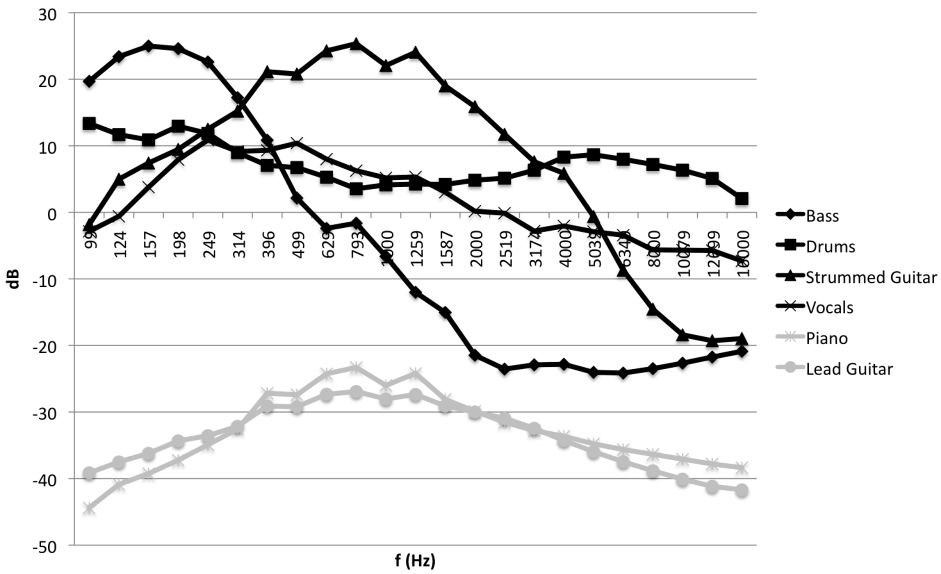



Figure 5.15: Piece 4 CIU Average Conflated LTAS

the lower-pitched elements. The main melodic information is also present but the rhythmic information provided primarily by the combination of the strummed guitar and drums seems to dominate.

Again, this is in contrast to the average mix of the NH group (as shown in figure 5.16, which shows the piano and lead guitar being particularly prominent across the spectrum, especially in the mid band. Again, it seems as if this mix has a strong rhythmic character but that this is merely a foundation, rather than the primary focus of the music or it’s defining character as is the case in each of the CIU group’s average mixes.

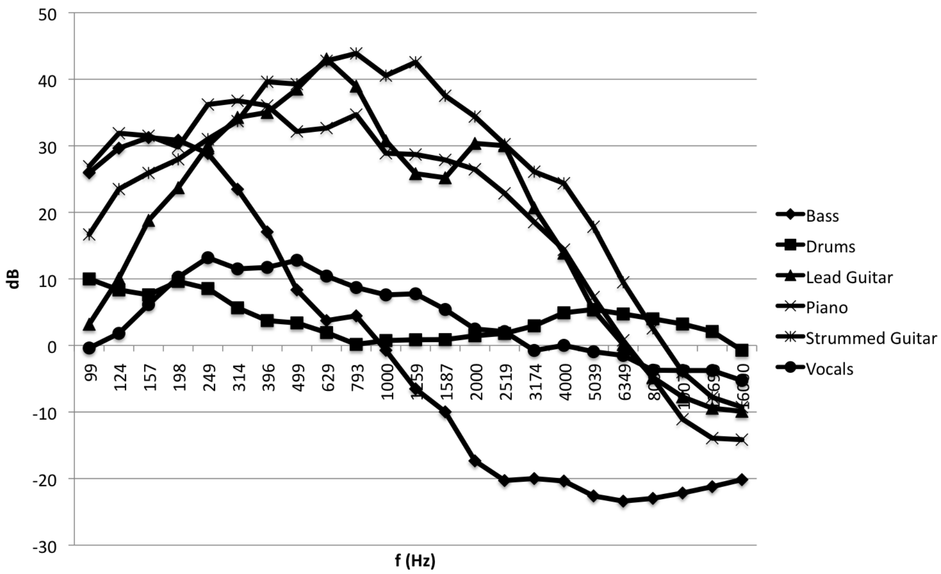
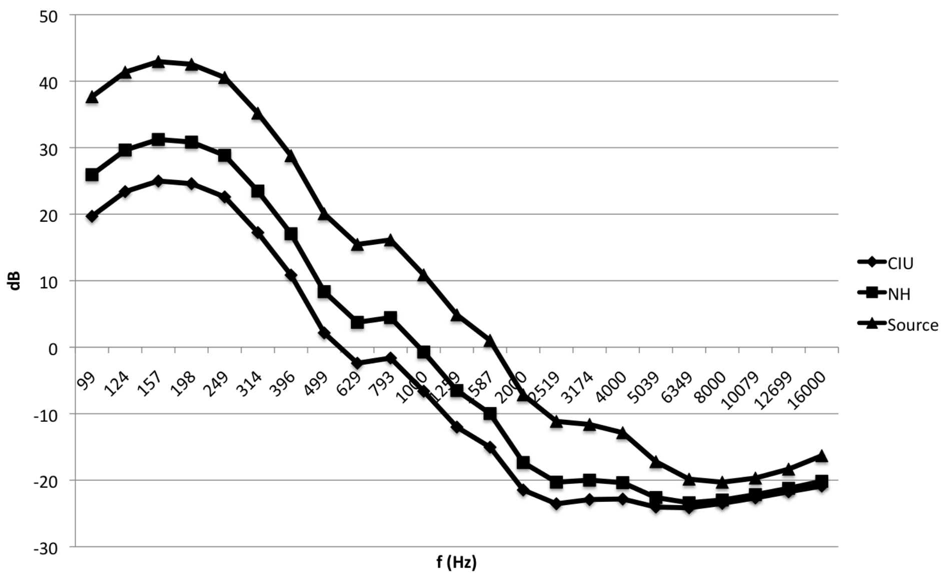



Figure 5.16: Piece 4 NH Average Conflated LTAS

### Individual Channels

### Bass



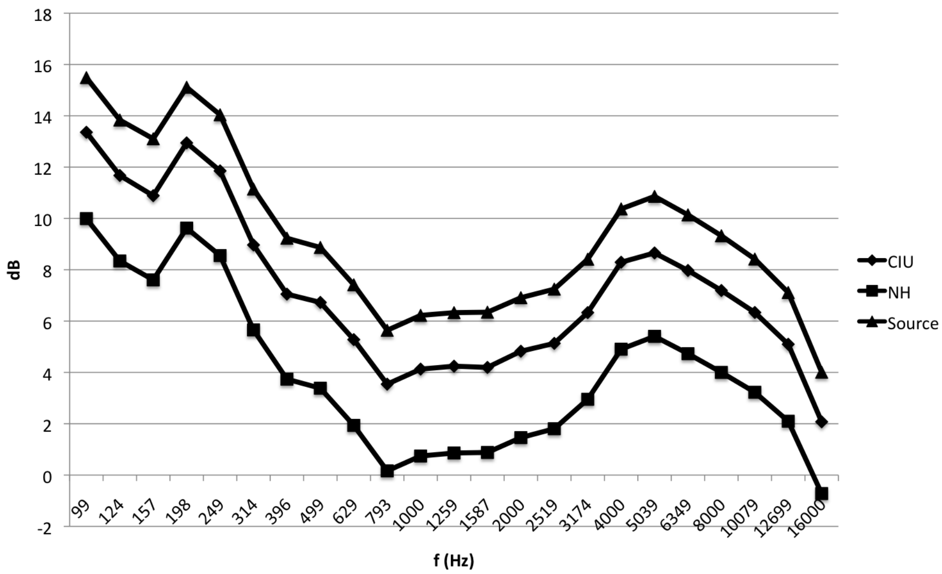

Comparing the LTAS of the average mix of the CIU group with that of the NH group we see that there is no significant difference across the spectrum but that the difference between the signals is significant in the low and high bands such that the CIU group

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p=ns | p<0.05 | p=ns | p<0.05 |
| CI Average vs. Source | p<0.01 | p<0.01 | p<0.01 | p<0.001 |
| NH Average vs. Source | p<0.05 | p<0.01 | p<0.05 | p<0.001 |

Table 5.34: Comparisons of Average LTAS for the Bass Channel - Piece 4

shows less energy across the spectrum. Comparing the LTAS of the CIU group's average mix with that of the source signal shows that the CIU group's average mix has significantly less energy across the spectrum and in each of the frequency bands. This also applies to the comparison between the NH group's average mix and the source signal.

**Drums**



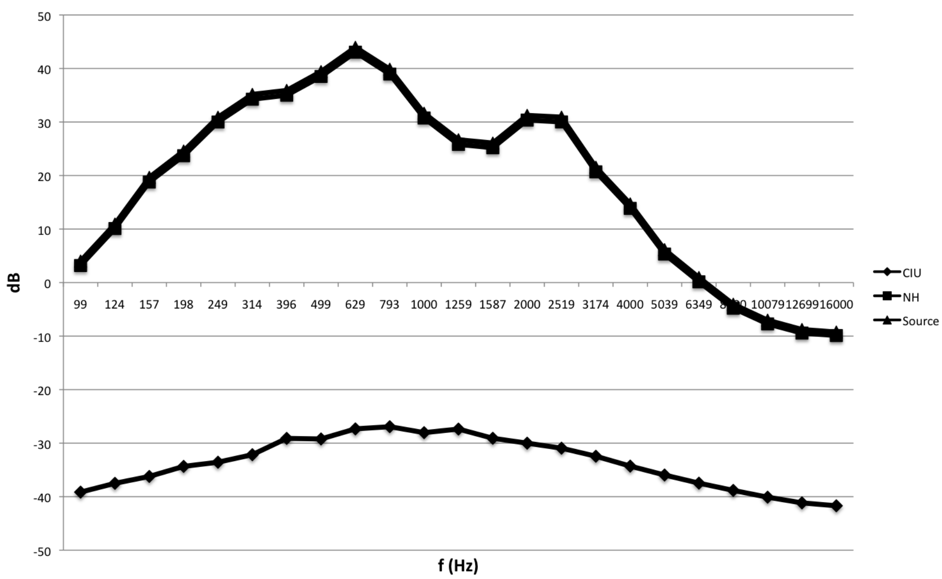

Data from the drums channel shows that there is a significant difference between the LTAS of the CIU group's average mix and that of the NH group with the NH group's treatment of this channel showing less energy across the whole spectrum. The CIU

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs NH Averages | p<0.001 | p<0.05 | p<0.001 | p<0.01 |
| CI Average vs. Source | p<0.05 | p=ns | p<0.001 | p=ns |
| NH Average vs. Source | p<0.001 | p<0.01 | p<0.001 | p<0.001 |

Table 5.35: Comparisons of Average LTAS for the Drums Channel - Piece 4

group's LTAS also differs significantly from that of the source signal across the whole spectrum but not, however in the low and high-bands despite showing more energy across the whole spectrum. Comparing the NH group's average mix with the source signal shows that the NH group's mix has significantly less energy in the drums channel across the whole spectrum.

### Lead Guitar



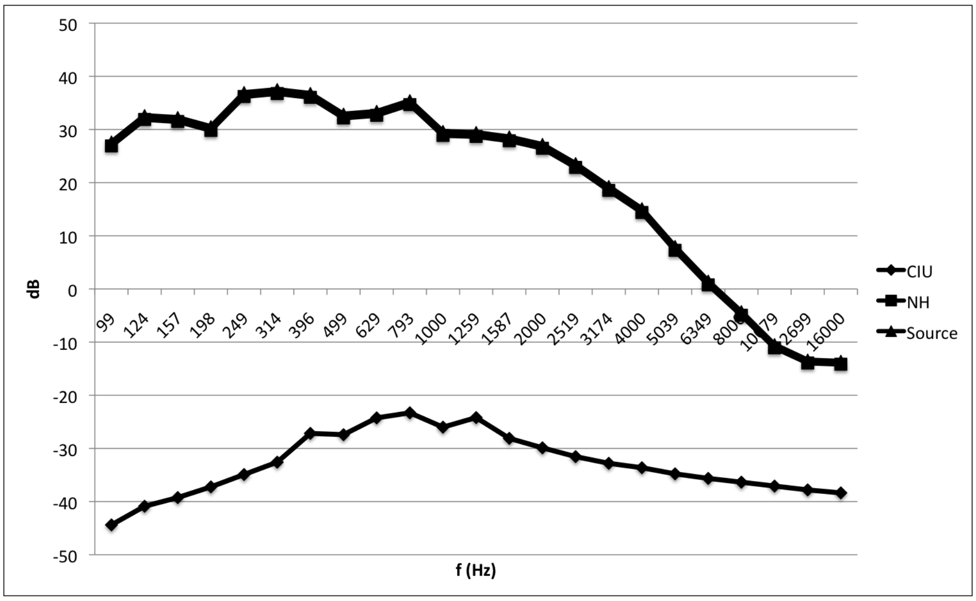

As the lead guitar was only included in three of the mixes by CIU participants we see that the average treatment of this channel for CIU group shows comparably less energy across the spectrum. A comparison of the LTAS of the average treatment of this channel

| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p=ns | p=ns | p=0.ns | p=ns |

Table 5.36: Comparisons of Average LTAS for the Lead Guitar Channel - Piece 4

by the CIU group with both the LTAS of the NH group's average mix and the LTAS of the source signals, we notice that there is a significant difference across the whole examined spectrum and in each of the three frequency bands. A comparison between the LTAS of the NH group's average mix and that of the source signal shows the signals to be almost identical with no significant difference across the spectrum or in any of the bands.

**Piano**

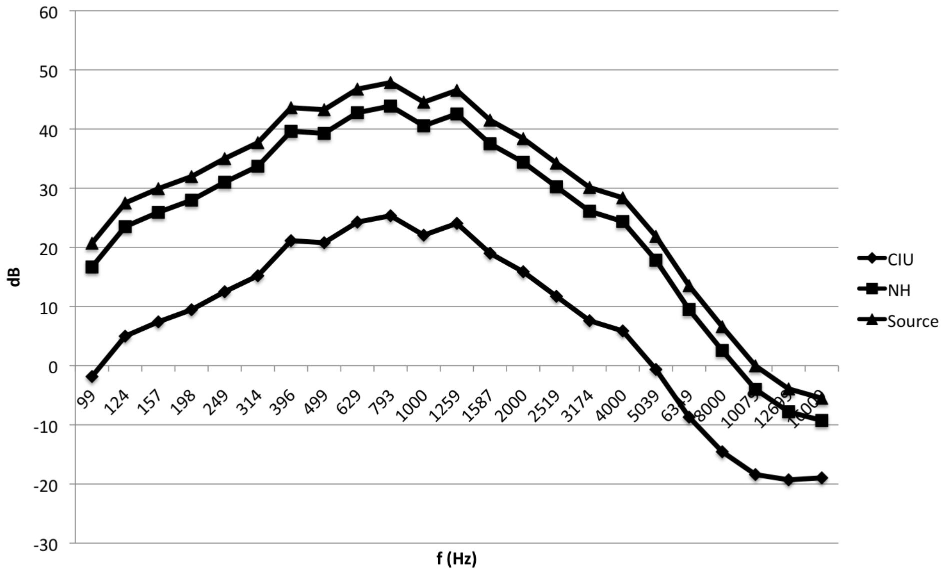



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.37: Comparisons of Average LTAS for the Piano Channel - Piece 4

As with the lead guitar, above, the CIU group's average treatment of the piano shows that it has considerably less energy across the spectrum than the NH group's average treatment of this channel or the source signal. This is due to the fact that only one CIU participant included this channel in their mix. When comparing the LTAS of the CIU group's average treatment of this channel to that of the NH group and the LTAS of the source signals we observe a significant difference across the spectrum and in each frequency band. There is no significant difference between the LTAS of the NH group's average mix and that of the source signal and these signals appear to be almost identical to each other .

**Strummed Guitar**

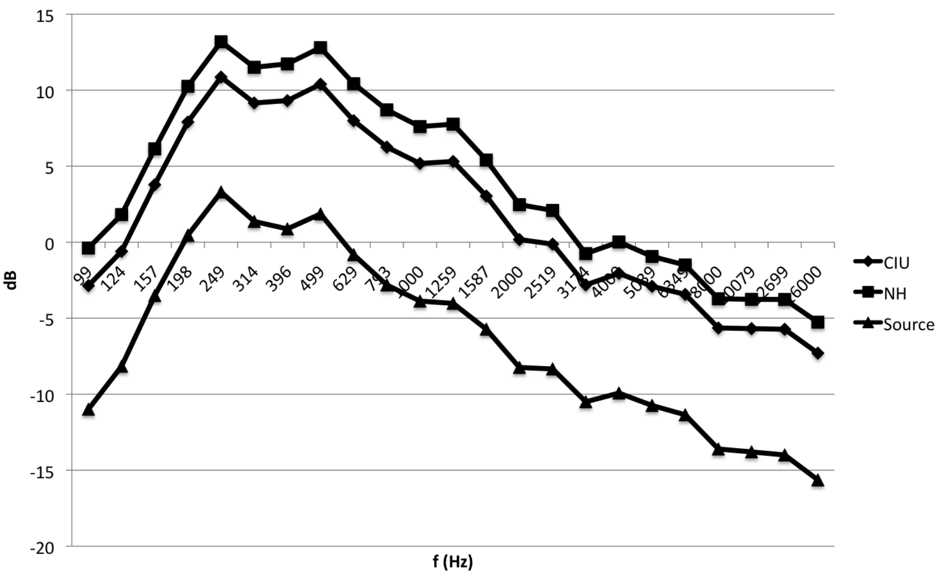



| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| CI Average vs. Source | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | p=ns | p=ns | p=ns | p=ns |

Table 5.38: Comparisons of Average LTAS for the Strummed Guitar Channel - Piece 4

Considering the LTAS of the CIU groups average mix of the strummed guitar channel in comparison to that of the NH group shows that there is a significant difference cross the spectrum and in each of the three frequency bands such that the CIU group's treatment of this channel shows less energy. When comparing the CIU group's average mix to the source signal for this channel we see that there is also significantly less energy in the CIU group's mix for this channel across the spectrum and in each band. The LTAS of the NH group's average mix, although lower in volume across the spectrum, is not significantly different to that of the source signal.

**Vocals (Male)**




| | Whole LTAS | Low-Band | Mid-Band | High-Band |
|---|---|---|---|---|
| Comparison | p = | | | |
| CI vs. NH Averages | p=ns | p=ns | p=ns | p=ns |
| CI Average vs. Source | <0.001 | p<0.001 | p<0.001 | p<0.001 |
| NH Average vs. Source | <0.001 | p<0.001 | p<0.01 | p<0.001 |

Table 5.39: Comparisons of Average LTAS for the Vocal (Male) Channel - Piece 4

For the vocal channel we see that the LTAS of the CIU group's average mix and that of the NH group are not significantly different across the spectrum or in any of the frequency-bands. Comparing the LTAS of the CIU group's average mix to the LTAS of the source signals shows that there is a significant difference between the groups with the CIU group showing significantly more energy for this channel across the spectrum. Comparing the NH group to the source signal shows the same result such that the NH group also has significantly more energy than the source signal across the spectrum and in each of the frequency bands.

### 5.4.5 Mix Comparison

Subsequent to mixing each of the four pieces of music, participants were played a one minute section of one of the pieces (randomly selected) two more times, once with their own mix and once with the original source signals and asked to compare them and state which version they preferred. These versions are: 'Music A' the mix that the user created during the study, and; 'Music B' the unaltered mix of the source signals for this piece. Table 5.40 shows the selections made by the groups:

| Group | 'Music A' (USER MIX) | 'Music B' (SOURCE MIX) |
|---|---|---|
| CIU | 7 | 1 |
| NH | 2 | 6 |

Table 5.40: Mix Comparison Preference Results

As can be seen from table 5.40, 7 out of 8 of the CIU participants preferred the sound of their own mix to that of the source mix which is consistent with the hypotheses (above). Interestingly, we see that the majority of the NH participants (6/8) prefer the sound of the source mix to that which they have created themselves. This shows that NH users benefit from professional mixes whereas CIUs do not but, instead, prefer the sound of mixes which they have tailored to their own individual needs.

### 5.4.6 Post-Mixer Questionnaire

After the mix comparison, participants completed a short questionnaire relating to the mixer and the effect it had on their musical experience. Questions and answers from this section of the study are presented below:

**Question 1: Did you find the mixer easy to use?**

100% (CIU and NH group) reported that they did find the mixer easy to use.

**Question 2: Were you able to use the controls to make the music sound pleasant and comfortable for you?**

100% of the participants reported that this was the case.

**Question 2b: Please provide details**

The following responses were provided when asked to provide details on the previous question:

| Control Details - CIU Group |
|---|
| "I could get rid of bad sounding instruments." |
| "Very easy to use to customise." |
| "It allowed me to reduce high pitches which can be unpleasant and the base sound made a little clearer." |
| "Making higher pitched sounds softer." |
| "Very easy and fun to use." |

Control Details - CIU Group

| Control Details - NH Group |
|---|
| "You can hear all the instruments." |
| "You can hear all the instruments." |
| "It was easy to make everything was at the right volume for my listening pleasure." |
| "You can hear all the instruments clearly." |

Control Details - NH Group

**Question 3: Did you find the mixer a useful tool for improving your music listening?**

100% of the participants report that they did find the mixer a useful tool for improving their music listening.

**Question 3b: Please provide details**

The following responses were provided when asked to provide details on the previous question:

| Control Details - CIU Group |
|---|
| “Yes, bad sounds could be made quieter or even gone, if I decide.” “Instrument selection simple and easy to use so can get used to different sounds of instruments.” “I felt it gave me more control over my listening and enjoying the different instruments.” “You can adjust various volumes for each instrument to make it easier to tell each instrument.” “Would like to have one for home.” |

Control Details - CIU Group

| Control Details - NH Group |
|---|
| “It helps to make the different parts stand out.” |

Control Details - NH Group

**Question 4: Did your experience of the music (whilst using the mixer) differ from your normal experience of listening to music?**

100% of the CIU group report that their experience did differ from that of their normal music listening.

**Question 4b: Please provide details**

The following responses were provided when asked to provide details on the previous question:

| Experience Details - CIU Group |
|---|
| “Yes - clearer. Could use to boost things I like to hear like drums or bass.” “You can control it better.” “Easier to make it sound like music.” “Able to adjust to my best preferences” “It enabled me to listen to individual instruments.” “Usually have to listen a few times to get tune and pick out different instruments able to adjust to suit what I need to hear.” |

Experience Details - CIU Group

75% of the NH participants also report that this is the case but no users in this group provide any comments.

**Question 5: Would you find it useful to have the opportunity to alter the sound of music in this way in future?**

100% of the participants report that they would like this opportunity.

**Question 6: Please give comments about the general sound of the music when you were using the mixer:**

| General Sound Comments - CIU Group |
| --- |
| "This could help a lot." |
| "When using the mixer it enabled me to adjust the level of sounds to my preference." |
| "Was fine - would have been better if i could have used music i was already familiar with. so much better." |

General Sound Comments - CIU Group

| General Sound Comments - NH Group |
| --- |
| "If there were any parts of music you didn't like they could be removed." |
| "It was very good." |

General Sound Comments - NH Group

**Question 6:**

Participants were asked questions relating to the perceived clarity of; (a) the beat/rhythmic elements of the stimuli, (b) the tune/melodic element of the stimuli, (c) the sound of the vocals, (d) the clarity of the vocals, (e) the amount of distortion, (f) the sound of the instruments.

| CIU Group | | | |
|---|---|---|---|
| Element of Stimuli | Clearer than Usual | Just the same | Less Clear than Usual |
| Beat/rhythmic elements | 100% | 0% | 0% |
| Tune/melodic elements | 100% | 0% | 0% |
| Sound of the vocals | 75% | 0% | 25% |
| Clarity of the lyrics | 75% | 0% | 25% |
| Sound of the instruments | 100% | 0% | 0% |
| | Less than Usual | Just the same | More than Usual |
| Amount of distortion | 100% | 0% | 0% |
| NH Group | | | |
| Element of Stimuli | Clearer than Usual | Just the same | Less Clear than Usual |
| Beat/rhythmic elements | 100% | 0% | 0% |
| Tune/melodic elements | 75% | 0% | 25% |
| Sound of the vocals | 62.5% | 0% | 37.5% |
| Clarity of the lyrics | 62.5% | 0% | 37.5% |
| Sound of the instruments | 75% | 0% | 25% |
| | Less than Usual | Just the same | More than Usual |
| Amount of distortion[5] | 0% | 0% | 100% |

Table 5.48: Reported Clarity of Musical Elements in Post-Mixer Questionnaire

### 5.4.7 Free Response Analysis

The following tables show the free responses provided by both groups when given space to provide general comments on the mixer and the experience of using it.

| Free Responses to Mixer Study - CIU Group |
|---|
| "Don't like listening to music much now but this could help thankyou." |
| "I love being able to listen to music as its a big part of my life still. So being able to create the sound is an advantage to me as it lets me make the sounds of different instruments more hearable.Using the controls on these tests was very easy for me and so this added to the pleasure of the whole thing . Zack has wrote CI-friendly music before which i found very pleasant not that long ago and he's very good to work with as he's seems also very interested in getting feedback from users and so he maybe able to improve things for implant users to enjoy music." |
| "I find that i can hear the voices better by making louder." |
| "I can make the melodies come up and out by losing other bits." |

| Free Responses to Mixer Study - CIU Group |
|---|
| “The test environment is very good and ideal for listening and makes me realise I should do more at home to emulate these conditions so that I may enjoy music more - very helpful! Too often I only enjoy music by connecting directly to my computer or iPod using my implant accessory cable.” |
| “The mixer allows me to enhance my choice of music and enjoy it more without having the droning sounds which I was only hearing previously.” |
| “Was easy enough to use, could maybe have had more time to be more accurate.” |
| “If someone made this for home I could vision myself listening a lot more because it makes things clearer and fun.” |

Mixer Free Responses - CIU Group

| Free Responses to Mixer Study - NH group |
|---|
| “Now i know how they make songs so good.” |
| “It was very good the way you have the choice to listen to what you want and block out things that are to loud.” |
| “It was easy to make everything at the right volume for my listening pleasure.” |

Mixer Free Responses - NH Group

## 5.5 Discussion

The results of this study show that amongst CIU participants there is a degree of variability in the way that they choose to mix multi-channel music, as hypothesised. This can be observed when considering the instruments included in the individual users' mixes which shows some users choosing to include all the instruments in the mix and other users choosing to include fewer instruments in their mix of the same music. This variability can be seen across all four pieces and, coupled with feedback from users stating that the mixer has improved their music listening, supports the theory that an individualised approach to music listening such as this one is valuable for CIUs. Put simply, as we have evidence of variability amongst CIUs in their approach to the mix, but unanimous feedback reporting that the clarity of musical elements and the general sound of music have improved, this suggests that: (a) CIUs have different *individual* preferences and needs and; (b) The music listening of CIUs benefits from the opportunity to create unique and *individual* mixes of multi-channel music. When considering the instruments selected by individual NH participants, however, it is clear that there is far less variability than in the CIU group and that, in the majority of cases, the NH participants choose to include all instruments in their mix.

This is further evidenced in the results which show the individual LTAS of each user's mixes. As can be seen from figures such as figure 1 of appendix E, there is a wide range of variability in the LTAS of CIU participants' mixes both in volume and in the shape of the spectrum. Again, considering this with regard to individuals in the NH group it is clear that, despite some inevitable variation, there is more uniformity than in the CIU participants, particularly relating to the shape of the spectrum.

With regard the individual differences amongst participants in this study, it is clear that CIU participants have benefitted from the opportunity to embrace such differences and manipulate music based on *their personal, individual* needs and preferences and although NH participants also show some variation, this is less than the CIU group. The result of the mix comparison which show the vast majority of CIUs preferring their unique version of the music, and the majority of NH users preferring the source mix, also highlights the fact that individualisation and the ability to manipulate the sound of multi-channel music is particularly useful for CIUs, impacting positively on their musical experience.

Considering group differences, results show that for each piece of musical stimuli, the LTAS of the experimental group (CIUs) is significantly different to that of the control group (NHs). The fact that the resultant mixes of CIUs versus NH participants are significantly different, immediately suggesting that these groups have different preferences. Therefore, with regard to the sensory experience (see chapter 1) and considering that common music listening situations such as listening to commercially released music or live music, for example, are mixed in a certain way which relates to artistic/technical decisions that do not, obviously, account for the range of needs audience members who are not normally hearing, hence, we can see why CIUs often report difficulties in listening to or engaging with music in this way. The mixer application has been a useful tool in establishing that there is a significant difference in the way that CIUs and NHs choose to mix multi-channel music and providing evidence for the fact that CIU participants have different listening preferences to NH users. This can also be seen in the result which shows that, across all four pieces of musical stimuli, the CIU group (on average) chose to include fewer audible channels in their mix than the control group who, in every piece (on average) chose to include each of the six available channels.

There were a core group of instruments in each piece that includes the drums, bass guitar, strummed guitar, lead guitar and piano, which is augmented in two of the pieces by vocalists (one male and one female, respectively) and in the other two pieces by the tenor saxophone. Considering the treatment of the core instruments in the average mixes we see that there is a large degree of continuity between the pieces. Looking at the LTAS results for each of the drum channels (i.e. one in each of the four pieces) we see that the CIU group's average treatment of this channel was considerably (and statistically significantly) higher in volume than that of the NH group's average mix or that of the source signals. This is consistent with the hypotheses set forth above and strongly supports the numerous reports from CIUs (many of which documented in this thesis) that music with a strong or prominent rhythm is well perceived and often enjoyed more as a result. Also, the fact that the rhythmic elements of music are reported to be one of the few structural elements of music that are well perceived strongly suggests a basis for the prominent drums and consequently strong rhythmic character of the CIU group's average mixes.

In each of the mixes, the LTAS of the average treatment of the bass for the CIU and NH groups are very similar to the source signals across the examined spectrum. This would suggest that, with regard to the sound of the bass guitar, the groups do not differ greatly from one and other. This finding is consistent with the hypothesis relating to the sound of elements that are typically reported as being well perceived by CIUs. Put simply, this suggests that the sound of the bass, in general, is well perceived by the CIU group who treat it in a very similar way to the NH group. This is also consistent with the findings from the MEQ study (chapter 3) in which many participants reported that the bass was an instrument that sounded particularly good. Additionally, it is not unreasonable to suggest that the bass may be one of the instruments that was well perceived as it is low in pitch, something which is frequently reported to be well perceived by CIUs and that, in this case, it was played quite rhythmically.

For the strummed guitar channel (in each piece) the CIU group's average treatment of this channel was mixed lower than that of the NH group or the mix of the source signals. The exception to this was the second piece of stimulus in which this guitar was played slightly differently to the other pieces. In this piece, although still presented as a strummed guitar, for part of the music it mainly provides rhythmic stabs on the second beat of the bar. In each of the other pieces the rhythm is more constant and 'dense'. The function of the strummed guitar part in each of the pieces (see outline of stimuli, above) is to provide harmonic information in a rhythmic manner. It is conceivable, when thinking about these musical elements, that this information is already provided by the combination of the bass and drums which are prominent in the CIU group's average mix and that this instrument is slightly redundant as a result. It is also a strong possibility that, due to the dense (i.e. rhythmically and timbrally) nature of this channel, that this is reduced in volume to avoid any masking which may occur if it was too loud. This may explain why the strummed guitar in the second piece, which contributes far less dense and complex information to the mix, was treated differently such that it was far more similar to the NH group's mix and the mix of the source signals.

The lead guitar, however shows a very different situation than that of the strummed guitar as in pieces 1, 2 and 4, the average treatment of this channel by the CIU group shows a signal that is considerably (and statistically significantly) lower than both the source signal and the average treatment of the NH group. This is due to the fact that it was either not included by the majority of the CIU participants in these mixes or included but at a low level. In piece 3, however, this channel is included by 6/8 of the CIU participants. The fact that this element has only been included as main audible channel (i.e. not a channel which has an LTAS showing very little energy due to a lack of inclusion in the mixes of individuals) in one of the average CIU group's mix suggests that it is an element that is not particularly well perceived. Given that in the stimuli, this instrument provides melodic information which could be considered as secondary to the main melody we can conjecture that this type of information may be problematic for CIUs, something which is also supported by claims from the MEQ study and from anecdotal evidence, i.e. that some instruments can obscure or mask the main instrument, such as vocals, for example. Interestingly piece 3 is the piece in which this instrument provides the main melodic information and is also the piece which shows the average mix for the CIU group includes this as a main audible channel.

In the case of the piano, an instrument which is frequently reported by CIUs as sounding unpleasant or problematic to listen to, we see that this was not included as an audible channel by any CIU participants in piece 1 but participant-CIU1 is the only CIU participant to include it in pieces 2, 3 and 4. Thus the *average* mix of the CIU group in piece 1 shows no energy for this channel and each of the other pieces show almost no energy for the CIU group's average treatment of the piano channel. The average mixes of the NH group however show that this instrument has been included in all four pieces. It is of particular interest to note that the participant mentioned above (CIU 1) did choose to include this channel in three out of four of their mixes (albeit relatively quietly) and that this participant reported, when asked about their musical background, that they had learned to play piano when they were younger. This provides some evidence for the idea that musical experience is not only dependent on the sensory experience but also on other categories of experience such as the cognitive experience, as is relevant in this case (see chapter 1) or the social experience which seems to pervade so many other areas of people's evaluation of musical experience. The memory of people's pre-implantation experiences of music can influence their post-implantation relationship with it, either positively or negatively, depending on many different factors. However, it is very interesting to see in this case that the pre-implantation experiences of one of the participants (i.e. the fact that they once learned to play the piano) seems to directly affect the way that they choose to mix music such that they are the only participant in this group to include the piano (which is often regarded as problematic by CIUs) in their mix. Examples such as this provide some explanation for why there is such variability in the reports of the perception and enjoyment of music by CIUs and the way in which this, coupled with previous experience, shapes the general musical experience.

A female vocalist is included in piece 1 and a male vocalist in piece 4 and in each case (male and female vocal), we see that the CIU group boosted the level of this channel so that it was significantly higher than the original source signal. In the case of the female vocalist, the CIU's average mix of this channel is significantly louder than that of the NH group but for the male vocalist, the NH and CIU treatment of this channel do not differ significantly. In each of these cases, the prominence of these signals within the mix is presumably related to the fact that there seems to be a natural inclination to consider the vocal element as the focus of the song. This is presumably due to the fact that this element of the music provides the main melodic information and the lyrics. CIUs often report, when talking about their usual musical experiences, i.e. day to day contact with music, that some instruments are not pleasant to listen to as the ‘drown-out’ or ‘obscure’ the vocals so it is difficult to hear what is being sung, for example, and that the musical experience suffers as a result. It seem then as if the vocal element of music is particularly important to many people and this seems to explain why this element of the music has been made to be so prominent in the average mix of both the CIU group *and* the NH group.

Finally, considering the saxophone which was only available as a channel in two of the four pieces of musical stimuli, we see that, despite 5 CIU participants including it as an audible channel in piece 1 that the average treatment by this group provides an LTAS which shows comparatively little energy across the spectrum. 4 CIU participants included this as an audible channel in their mix of piece 3 but, again, this provides an LTAS showing relatively little energy across the spectrum. This obviously shows that although some participants chose to include the saxophone channel in their mix, that they did so at a low level, hence the low level in the average treatment of this channel by the entire CIU group. Probable reasons for the fact that this instrument was not particularly prominent (on average) for the CIU group are similar to those for the lead guitar, as outlined above. More specifically it was presumed that this instrument, which mainly provided secondary melodic content, may have detracted from the sound of other instruments and may have presented problems such as masking or obscuring other important material, for example. Reports from the MEQ study (see chapter 3) and responses to ’Deacon’ (see chapter 6), however, suggest that the saxophone is an instrument which is generally well perceived. However, individual differences in the sensory experience of participants, coupled with the instrument’s musical application in the context of this stimuli may account for the fact that it has not been included in the average CIU mixes in this case.

When considering the average mixes of each piece (i.e. mix of all audible channels) we see that, in general, the CIU group have significantly less energy across the spectrum than either the NH group or the mix of the source signals. This, in one respect, may have been expected due to the fact that the CIU mixes have at least two instruments less than either of the mixes they are being compared to. On another note, however, this is extremely interesting as it suggests that CIUs choose to mix music so it is quieter across the spectrum (in general) than the average mix of the CIU group. The fact that the average mixes of the CIU group are generally quieter than the average NH mixes may be due to the smaller dynamic range (approximately 30-60dB, depending on the system) of CI systems in comparison to normally hearing auditory systems (120dB).

The user feedback gained from this study is particularly important as it is the area from which we can begin to understand the experiential effects of the mixer application. It is important to note that CIU participants commonly suggested that they felt ‘in control’ or ‘enabled’ or that they ‘had a choice’ when using the mixer application. Some particularly useful pieces of user feedback (from different users) were:

‘...Could use to boost things I like to hear like drums or bass.’

‘I find that i can hear the voices better by making [them] louder.’

‘Easier to make it sound like music.’

‘You can control it better.’

‘When using the mixer it enabled me to adjust the level of sounds to my preference.’

‘The mixer allows me to enhance my choice of music and enjoy it more without having the droning sounds which I was only hearing previously.’

‘I can make the melodies come up and out by losing other bits.’

These are particularly interesting as they provide further evidence that individual users used the mixer to create a mix that suited their own listening preferences.

Another theme that emerged from the user feedback was the suggestion that the mixer application could be beneficial to their musical experience and that they would like to use it again:

'This could help a lot.'

'The test environment is very good and ideal for listening and makes me realise I should do more at home to emulate these conditions so that I may enjoy music more - very helpful!...'

'If someone made this for home I could vision myself listening a lot more because it makes things clearer and fun.'

Another important issue based on the feedback from users is the mix comparison. As was noted above, immediately after mixing each of the pieces of music, participants were played two versions of the same piece, one of which was the mix that they had created (personally, not the average mix) during the mixing process and the other was a mixed version of the source signals. The fact that the vast majority (7/8) of the CIU group selected their own mix (as opposed to 2/8 of the NH group) as preferable to the pre-mixed version of the music, on a blind test, is also indicative of the fact that the mixer application has had a positive impact on the way that the music sounds to them. This is a very important result for two reasons, firstly, it supports the argument that CIUs have *individual* listening needs and preferences, and secondly, it provides evidence for the mixer's value as a tool for improving music listening for CIUs, something which is largely confirmed by the answers provided in response to the post-mixer questionnaire (details above). A final point to emphasise, with regard to the mix comparison result, is the fact that the majority of the NH group preferred the professional mix of the source signals despite the majority of the group stating that they felt most musical elements were clearer when using the mixer and that they enjoyed the experience of doing so. This suggests that the value of the mixer is not simply novelty or the fun of experimenting with the sound of musical instruments, for example, as both groups report that the mixer was useful in improving the sound and experience of music; however, when asked to compare the product of their mixing session with a mix of the source signals NH users still preferred the professional mix to their own.

In general, results from the CIU group show that they found the mixer easy to use in order to make the music sound pleasant and comfortable on an individual level and open responses providing details on this mention the ability that the mixer provides the opportunity to '. . . get rid' of sounds that are unpleasant, or 'reducing' elements that may be problematic, for example. This suggests that some participants are intuitively using the mixer in order to eliminate or de-emphasise 'problem areas' which is very encouraging as it suggests that the rationale for developing this application was well founded and that this could potentially be used as a useful tool to improve the sound of multi-channel music - something which is also reported by 100% of the participants in the CIU group.

An important result was that all of the participants in the CIU group report that their experience of the music (whilst using the mixer) was different to their usual experiences. The comments from participants in this group suggest that the music was (or could be made to be) clearer, something which presumably has a positive effect on the sensory experience. In this case there is also a strong suggestion that the feeling of being in control and that the participants can take steps to adjust the music for *their* needs, is a positive aspect that benefits the general musical experience. This is echoed by the fact that participants, particularly those in the CIU group, would like to have the opportunity to use this application in future. From the free responses provided by the participants (discussed above) when asked to provide any general comments on the study, it is also obvious that the mixer application and the opportunity to manipulate the sound of music in this was is something which participants find useful and beneficial to their musical experience.

## 5.6 Conclusions

Results show that, when presented with the opportunity to manipulate the sound of multi-channel music in the way described above, there is variability amongst users with regard to the instruments chosen to be included in mixes and in the LTAS of these mixes. Such variability in the mixes is particularly noticeable amongst CIU participants, however, user feedback shows that the mixer was unanimously regarded as a useful tool for music listening which has a positive effect on the sound of the music and on the way that the music is experienced. This is clear evidence that *individual* users are able to use the mixer to improve their music listening by tailoring the sound of music to their specific preferences and listening needs.

This study also illustrates the fact that the average mixes of CIUs and of NHs are significantly different thus suggesting that these groups have different listening needs, when aiming to create a pleasant and comfortable sound. This highlights the differences between CIUs and NHs with regard to music listening and is a basic but very important issue to acknowledge if meaningful strategies for the improvement of musical experiences of CIUs are to be developed. As most music (certainly at a commercial level) is created (i.e. composed, recorded, *mixed* and mastered) and distributed with normal hearing audiences in mind it is not difficult, in light of the results of this study, to see why CIUs often find this type of listening experience difficult. Additionally, the degree of variability within the CIU group means that any potential solution to this problem should not be universal or aim to provide some sort of blanket remedy which aims to deal with CIUs as one homogenous group. Rather, attempts to deal with problems associated with music listening of this nature should aim to be as individualised as possible so that CIUs can manipulate the sound of music in a way that is particularly suitable for their individual, unique needs as was the case in this study, for example. Despite individual differences, it is also important to draw attention to the fact that results generally support the current evidence (both anecdotal and otherwise) that CIUs report a preference for music with a strong rhythmic character and that lower pitched musical sounds are often preferred.

With regard to evaluations of the musical experiences of participants, results show that this application was widely regarded as a positive influence with people reporting that they felt in control or that they had 'control' and a 'choice' with regard to the sounds that they heard. Additionally, the fact that participants report that they would like to have the opportunity to use this programme again suggests that this had a positive effect on their musical experience. Support for this can be found in the result which shows on a blind A:B comparison of two pieces of music, the vast majority of the CIU group stated that they preferred the sound of the mix which they had created previously. Also, the fact that the CIU group note that they felt able to 'get rid' of sounds that they found problematic, or conversely, that they could boost the level of the instruments which 'sounded good' suggests that participants were engaging in the process appropriately and using the application in the way in which it was intended to be used.

This chapter has shown that there is considerable and (in most cases) statistically significant differences in the way that NH and CIU participants choose to mix complex multi-channel music. Such results highlight the nature of the differences between the groups and provide interesting information regarding the elements of music which are most successfully perceived and enjoyed by CIU participants and those which may be potentially more problematic. Highlighting this point is particularly important as it allows us to describe more confidently the differences that exist between CIUs and NHs with regard to music listening, particularly with regard to the sensory experience (see chapter 1). Individual differences within the CIU group are also important to draw attention to as they highlight the very need for individualised measures such as this mixer application for the improvement of the musical experiences of CIUs. More work is needed in this area and I believe that the development of the mixer would be greatly beneficial to the music listening, particularly with regard to the sensory experience, of CIUs. However, considering that this system is in it's infancy, I believe that measures should also be taken which aim to improve other areas of the musical experience and that deal with issues of communal music listening.

On this point, the following chapter details the composition and development of a ‘musical’ which was composed specifically for CIUs but which aims to be enjoyable for CIU and NH audience members alike in an attempt to promote a positive musical experience by addressing elements of the sensory, cognitive and social/environmental experience, as proposed contributors to the general musical experience.

# Chapter 6

# Deacon

## 6.1 Introduction

Chapter 1 outlined a framework for the way in which the concept of musical experience is approached in this thesis. In short, three general categories were proposed that relate to issues contributing to one's musical experience, namely; (a) sensory experience, (b) cognitive experience, and (c) social/environmental experience. The current chapter is an explanation and discussion of the composition and production of a 'musical' that was written specifically CIUs. Consideration will be given to the way in which this 'musical' relates to each of the aforementioned categories by way of considering it's potential impact on the musical experience of audience members (either live or on CD/DVD). Previous chapters (4 and 5) considered the way in which recorded music can be manipulated or altered, by way of making the sound more suitable to the music listening needs of an individual CIU. However, such manipulation of recorded sound does not have a bearing on the wider social experience of music as discussed in previous chapters, due to it's focus on individualisation.

It is clear from evidence provided throughout the thesis that various factors relating to the sensory experience of music (pitch perception or instrument identification, for example) have considerable considerable impact on the general musical experience of CIUs. As discussed in previous chapters, there is a lot of variation in the reports of music perception from CIUs, which manifests itself in different ways with regard to the evaluation (and future pursuit) of musical experience; largely because the evaluation of music perception is also compounded by personal variables, as opposed to musical ones (see chapter 3 for a detailed discussion). However, with regard to the perception of structural elements of music, this research has shown that there are many similarities in the reports of CIUs, such as a general preference for: low-pitched musical sounds, percussive instruments/playing styles, drones, male singers, and music with a strong rhythmic character, for example (see chapters 2 & 3 for more details).

By analysing such reports it has been possible to generate a general schema to inform a musical composition written specifically for CIUs and these issues will be discussed below. In addition, with respect to the important social and cultural aspects of music listening (see chapters 1, 2 and 3) it was also considered of great importance that the music would also be enjoyable to NH audience members. This was of particular significance as the rationale for composing this music was to provide a positive musical experience; in the context of a live performance the social experience could be a particularly important contributor to the general musical experience. This involves access to social aspects of music listening that would aim not to alienate the CIUs or their NH family/friends/fellow-listeners, for example.

The composition of the 'musical' described in this chapter was commissioned by MED-EL UK and premiered to a mixed audience of CUIs and NH audience members on Saturday the 19th of September 2009 at the Scottish Storytelling Centre, Edinburgh. An evaluation of the audiences' appraisal and reaction to the composition and performance was conducted by Geoff Plant, on behalf of MED-EL UK. I have, gratefully, been given full access to the results of this study and will present a summary of this information later in this chapter.

It was agreed mutually between myself and the commissioners that the 'musical' would tell the story of 'Deacon Brodie', an infamous historical figure of Edinburgh who lived a double life as a respected cabinet-maker and city councillor, by day; and as a thief, gambler and womaniser, by night. As a result, this work was advertised and performed as a 'musical' entitled 'Deacon'. I believe that this composition taking the form of a 'musical' is a valuable idea that has many potential benefits to the audience, particularly the CIU contingent; something that relates, at least in part, to the second of the categories noted above (i.e. cognitive experience). Having a thread of a common theme, especially one that outlines a story, running through the music allows for each piece to be contextualised within a larger framework of comprehension. If there are elements of a particular piece that are not well perceived/experienced and consequently, understood, then comprehension can be gained from it's context within the whole work. For example, if the structural elements of music (or part thereof) do not comply with an individual's listening needs (with regard to the sensory/cognitive experience), this does not necessarily mean that the whole experience is compromised as the listener is presumed to be likely to gain understanding by analysing any such poorly perceived material in the context of the whole piece or, the musical in general.

Thus, the presence of a story or narrative can serve to construct an important cognitive schema for the 'musical', within which greater potential for positive musical experience lies. As a result, each piece of music was preceded with a short animated narration (as can be seen in the DVD in appendix H) of approximately thirty seconds in duration, which was projected on-stage in order to inform the audience of the progress of the story and context of each piece within this framework. These animated narrations were also subtitled in order to ensure that the audience had the appropriate access to the information presented. Additionally, those pieces in the show with vocals also had the lyrics projected during the performance (and included as an option on the DVD version).

In order to demonstrate the relevance of this music to the listening needs of the target audience I will consider known issues relating to a number of musical elements and give examples from 'Deacon' which illustrate the way in which such elements have been dealt with.[1] Such elements include: instrumentation, rhythm, pitch and melody, chords and harmony, timbre and orchestration and relevant cultural issues. In addition, studies pertaining to the music perception of CIUs are often compartmentalised such that individual elements are considered separately, and has been outlined in such a manner in chapter 1. I will continue this approach in this chapter by considering each in turn before outlining the way in which the music has been appraised by CIUs.

## 6.2 Instrumentation

Instruments were selected primarily because they had been frequently reported as instruments that sound 'good' or 'pleasant' by a number of CIUs (see chapter 3). The instruments selected were: a male vocalist with a folk/traditional background (i.e. not a classically trained singer), cello, tenor saxophone, acoustic guitar, electric bass guitar and a drum-kit (minus the crash and ride cymbals). In a later performance of the show (February, 2010) in which the room and stage were smaller than that of the previous

[1]Please note that full scores for the entire 'musical' are included in appendix G

performance the drums were substituted for a percussion setup of djembe, cajon, kick-drum and shakers in order to prevent the drums/percussion from being too loud or overpowering. Additionally, the acoustic guitar was substituted for banjo in one piece in an attempt to reduce the sustain in the arpeggiated sections (Thieves and Rogues, see appendix G). The decision to write this music for a small ensemble of this nature was taken due to reports from CIUs regarding problems associated with instrument/timbre and melody recognition in music performed by large ensembles (see chapters 2 and 3).[2]

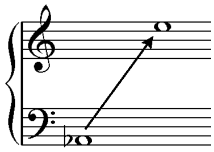
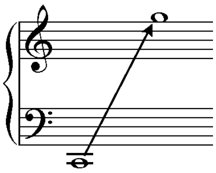
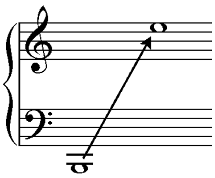
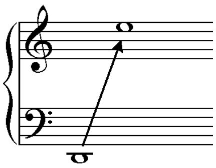
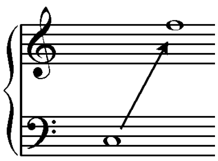
| Instrument | Range |
|---|---|
| Tenor Saxophone |  |
| Cello |  |
| 6-String Electric Bass |  |
| Acoustic Guitar (DADGAD)* |  |
| Tenor Banjo (CGDA) |  |
| * In standard tuning the extremities of this range are a tone higher than illustrated here. | |

Table 6.1: Instrument Ranges Example

Table 6.1 illustrate the wide range of pitches that can be produced by the instruments in this ensemble. The playing ranges included in table 6.1 above are conservative indications of the range of pitches playable by each instrument (signified by the arrows -

[2] Looi et al. (2008) also provide evidence for poorer instrument discrimination in larger ensembles.

the brackets signify the ranges used in the compositions); in many cases, these ranges can be increased as a result of the instrumentalist's technique, for example.

## 6.3 Outline of Musical

Table 6.2 outlines the 'musical' section-by-section and gives details of instrumentation.

| Section | Instrumentation |
|---|---|
| Introduction video | Subtitled Voiceover |
| Prelude | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Introduction video | Subtitled Voiceover |
| Dreams | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Video Sequence | Subtitled Voiceover |
| Ceilidh | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Video Sequence | Subtitled Voiceover |
| Deacon | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Video Sequence | Subtitled Voiceover |
| If I'm Honest | Drums, Bass, Guitar, Vocals |
| Video Sequence | Subtitled Voiceover |
| Thieves and Rogues | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Video Sequence | Subtitled Voiceover |
| These Fools | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Video Sequence | Subtitled Voiceover |
| Turning King's Evidence | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Video Sequence | Subtitled Voiceover |
| To Hang by the Neck | Drums, Bass, Guitar, Sax, Cello, Vocals |
| Conclusion video | Subtitled Voiceover |

Table 6.2: Outline of Deacon

## 6.4 Rhythm and Rhythmic Elements of the Music

The terms 'rhythm' and 'rhythmic' are ones that are often used in discussions about CIUs and 'successful' music perception, both in anecdotal and scientific contexts (see chapter 1). However, when considering the musicological meanings of the term rhythm and it's derivatives, it becomes clear that this term is often used in a somewhat ambiguous manner. In chapter 1, consideration was given to the perception of rhythm with regard to cochlear implants and it was suggested that, in a general sense, it is musical variables of this nature that are often most successfully perceived by CIUs. This is based on studies in which rhythmic elements were found to be perceived by CIUs almost as accurately as by NH participants (REFS) and is supported by many anecdotal accounts of music listening by CIUs.

With regard to elements of rhythm in the current context, however, this does not simply mean the signal produced by the drums or percussion but, rather, the comprehension of the durational/temporal elements of music within a given structure; that is to say, the various patterning possibilities and durations of temporal events within a musical context. I feel it is necessary to explicate this point due to confusions that frequently occur in conversations (with CIUs and hearing professionals, alike) relating to the nature and origin of 'rhythm' in music. For example, in many cases (from personal experience) people often believe that if a signal is being emitted by an instrument that is producing discernible pitches, that the result is a 'melody'. Although this could be the case, I believe that it is important to realise that a melody could be considered as a series of pitches, which are mediated by rhythm  i.e. organised temporally and durationally. Thus, if a signal is understood and described as a melody, it will have a rhythmic component, which I believe to be no less valid than the pitch-based component. Thus, it is important to realise that rhythm is a musical element that is not simply limited to those signals produced by the drums/percussion, for example.

An approach to rhythm, when composing to suit the general listening needs of CIUs, should focus on the presentation of patterns and structures that can be used to emphasise elements of the music that promote temporal and contextual comprehension. For example, if a listener is confused or disorientated with regard to the progression of the music (a frequently reported situation in the MEQ study  see chapter 3), then prominent rhythmic structures, which are often reported to be more successfully perceived, can provide valuable musical information to attend to. In some cases this may also provide a predictable, repeating beat that can be used as a simple and effective element to focus on and as a way of gaining an understanding of the temporal progression of the music. In addition, if rhythmic elements (again, not necessarily those performed by drums/percussion, for instance) are prominent and interesting, where appropriate, then this can provide musical value for those listeners who may find it difficult to engage with the music on anything other than a rhythmic basis.

Consider figure 6.1, an extract from 'Viva la Vida' by the band Coldplay (Martin et al., 2008), which illustrates the use of an interesting and engaging rhythm (and combination of rhythms). This is an example of a piece of music that has very discernible rhythmic elements despite using very little percussion which served as an inspiration for considering the importance of prominent, distinctive and interesting rhythmic structures.


Figure 6.1: Distinctive Rhythmic Structures Example

As we can see from figure 6.1 the string section provides the main rhythmic focus in this piece, something that is also immediately obvious when listening to the recording. This is then joined by the kick drum, which plays four crotchet beats per bar thus serving to enforce the pulse of the music and highlighting the way in which the string section alternates between playing on the beat and providing syncopated accents. Essentially, this is an example of the way in which; (a) strong rhythmic elements can be included in the music without relying on percussion, and; (b) the way that combinations or layers of rhythms can be built up to form interesting rhythmic structures; in this case, the combination of distinctive string section rhythm and the steady, predictable pulse of the kick-drum. This generates a multi-layered rhythmic environment that allows (and perhaps encourages) people to attend to different rhythmic aspects of the music.

Such layers of rhythmic organisation can be found in the second half of the first piece of 'Deacon', namely 'Prelude', an excerpt of which is shown below (see appendix G for the full score and appendix H for the CD/DVD recording). After a slow section in 3/4 at the start of the piece, the music changes to common time and a militaristic, march-like drum pattern starts. As can be seen in figure 6.2, the cello enters doubling the snare-drum rhythm. The bass plays a syncopated line that was written to contrast the militaristic, uniform nature of the cello and drum-kit part, firstly in order to make it more prominent (due to the contrast) and, secondly, in order to create some interesting rhythmic contrasts in the music. This is, not to say that there is any sense of competing or crossed polyrhythms, simply that this adds an extra layer of rhythmic information that distinguishes itself from the other concurrent elements. Additionally, towards the end of most phrases, the saxophone doubles the bass part when it is not playing long sustained notes which, also adds another layer of rhythmic (and timbral) interest.


Figure 6.2: Rhythmic Layers Example

This example serves to illustrate the way in which the drums have been used as the rhythmic foundation of this section of the music, with the cello being added to emphasise this rhythm whilst also implying the harmony. This rhythmic foundation is built upon by the bass, which also plays a contrasting part thus allowing the bass line to stand out against this foundation and add a sense of urgency to the music by anticipating the downbeat of each bar by a quaver. The saxophone's relatively long sustained notes serve as another contrast to the overall rhythmic structure in the first half of the phrase in an attempt to provide these notes with sufficient space (rhythmically and timbrally) to be distinguishable and to provide a sense of melody. For the latter half of the phrase the saxophone doubles the bass line so that the rhythmic patterns become the most prominent elements of the music again. In this rhythmic environment the drums obviously play an important role, however, a great deal of the rhythmic content comes from the way in which the other instruments are played and the way in which they interact with each other. In this sense it could be suggested that, although the instruments are providing melodic and harmonic information, this is somewhat secondary to the rhythmic structures that are built up in this type of arrangement. Given that this is part of the first piece of music in the show, the intention was to appeal to the the idea that the rhythm (in a general sense) is well perceived, in the hope that this would relax and reassure an audience who may be generally characterised by those people who admit to being intimidated, confused or even upset by their implant-mediated music listening experiences.

In the following example, an extract from the song ‘Dreams’ (see appendix G for the full score), the saxophone and cello are used in a primarily rhythmic manner in order to provide additional accents to the music. In this piece the vocalist is, for the majority of the song, the primary focus as his part provides both the main melody and the words, i.e. the linguistic component of the song. With this in mind, it was important that the orchestration was not so dense that the vocals would be obscured. As can be seen from figure 6.3, the drums and bass play very repetitive rhythms that do not detract from or interfere with the vocal phrasing and, from a harmonic point of view, the bass outlines the harmonic progression very simply and in a way that is appropriate to the musical (stylistic) situation. The guitar provides more rhythmic interest by contributing rhythmic strumming patters that adhere to the ‘folk-song’ style of the music and enforces the 6-8 time.

The unison line played throughout this section of the music by the saxophone and cello is another example of how front-line instruments can be used to create interesting rhythmic structures. Again, if we consider that perception of pitch may be problematic for some CIU listeners, we can see that this line still contributes interesting and valid musical information. Put simply, if the pitch components of this line are poorly perceived, the distinctive rhythm will hopefully add to the overall rhythmic context in a meaningful and musical way that provides interest for the listener and a repetitive feature that may aid comprehension of the music if other elements are poorly perceived.

Figure 6.4 is taken from the piece ‘Ceilidh’ (see appendix G for full score) which is largely an arrangement of a number of Scottish traditional melodies. The example below is an arrangement of one such melody ‘Johnny Cope’ which is played by the cello with backings from the bass and the guitar. As can be seen from the score, the bass plays a repeating note, which provides the pulse of the music in a simple and deliberate manner whilst the guitar plays a more complex rhythmic pattern; this is also played staccato and is palm-muted in order to prevent the notes ringing and to maximise the percussive impact of the part. It should also be noted that the melody has been harmonised so that the bass and guitar pedal an A throughout, despite the fact that the melody suggests changes in harmony (although, largely in A minor). This decision was made so that the


Figure 6.3: Rhythmic Accents Example

parts played by the bass and the guitar would (primarily) collectively contribute to the rhythmic feel/groove of the music with the melodic and harmonic elements a secondary consideration. Consequently, the cello plays the melody in a higher range so that there is a degree of separation between this and the backings in order for it to remain the primary focus of this section of the music.


Figure 6.4: Rhythmic Groove Example

The examples noted above serve to illustrate, at least for the purposes of this composition, that the idea of rhythm is one that takes account of the way in which various elements (not only those presented by percussion instruments) coalesce and combine to form structures of rhythmic information. Consequently, throughout the music, there are many areas in which the harmonic and melodic content are less important than other aspects such as rhythm. This is to say that the successful perception of the melodic and harmonic elements of the music is not essential for a positive perceptual experience. In some cases the ability to hear the onset of musical events within a temporal context can provide access to rhythmic structures thus maximising the potential for positive aspects of the perceptual experience to be achieved despite potentially poor perception of pitch or spectra, for instance.

## 6.5 Pitch and Melodic Elements of the Music

As has been discussed at earlier points in this thesis, there are arguments (supported by anecdotal evidence and some scientific data), which suggest that many CIUs benefit from hearing musical sounds of lower-pitch, rather than higher. As was discussed in previous chapters (see chapters 1 and ch:meq) this is potentially related to the fact that lower pitches provide greater access to harmonic (i.e. spectral) information. In general, the majority of CIUs state that the instruments that they prefer listening to are those which typically present lower pitches, or indeed, the lower regions of instruments such as the piano or trombone, for example (see chapter 3, for details). Given the reports suggesting that CIUs have, in general, better experiences of lower-pitched musical sounds, this was a major consideration in the criteria for composition and also had an impact on the instrumentation and orchestration processes.

With regard to higher-pitched musical sounds, there is also a great deal of anecdotal evidence suggesting that sounds of this nature can cause distortion and can, in turn, have a masking effect on other instruments. Therefore, the use of high-pitched musical sounds was also an important consideration when generating criteria and composing music of this nature. It should be noted that the terms high-pitched and low-pitched are relative terms and are, to an extent, subjective. Although it is easy to comprehend the meaning of these terms in a general sense, the boundaries between pitches of the lower and higher brackets are extremely vague. Therefore, this issue was one that will be very important and requires delicacy and sensitivity; extremes were avoided and caution should was exercised when dealing with pitches in the upper registers of instruments capable of producing high-pitched sounds. This is not to say that pitches that could be considered as 'high' are not used, but rather to say that, when included, they were be treated in a way that: (a) was sympathetic to the musical context, i.e. no sustained high pitches played while other important musical information is being presented in order to avoid any potential masking (b) that considers the known experiences of CIUs in a general sense and (c) is appropriate to the style and feel of the music at the point of use.

As can be seen from the indicated playing ranges of the instruments included in this composition (above), each has a reasonably wide range available. Therefore, it was important to aim to use the lower regions of these playing ranges, for the most part, in order to avoid any problems associated with the perception of higher-pitches. This is also the case for the range of the male vocalist.

Such discussions relating to instrumental range and the use of pitch areas, for example, relate to the treatment of melody in this composition. As has been outlined above, pitch content was treated carefully and this was also the case for the setting of melodies with regard to tessitura, range and the timbral implications of such. As a result, there are three important ways in which melody has been dealt with throughout this composition. Namely; (a) the inclusion of 'traditional' or culturally 'familiar' melodies, (b) repetition of melodic content, and, (c) the presentation of melodic content in a way that is distinctive from the rest of the concurrent material.

With regard to the inclusion of melodies that are either 'traditional' or 'familiar' in a cultural sense, this approach permeates most pieces of music in this composition. A clear example of this can be seen in the third piece 'Ceilidh', which is an arrangement of a number of traditional melodies including 'Johnny Cope', 'The Dashing White Sergeant', 'The Bonnie Banks of Loch Lomond', 'The Gay Gordons' and 'Auld Lang Syne'; the cultural significance of which will be discussed below. This piece treated each of the tunes differently in order to create a distinct style and mood for each. The importance of this music being largely 'traditional' means that it will, presumably, be familiar to many people, thus immediately placing it within a cultural framework in addition to the narrative framework of the storyline (as discussed above).

Other pieces provide example of how such styles are emulated in order to create melodic content that could be described as culturally familiar. See the example taken from 'Prelude', below, for example. Essentially, it was hypothesised that music that was either explicitly recognisable (such as the traditional melodies), or that was written in a similar style, would provide more of a coherent cultural framework and thus potentially aid comprehension and enjoyment for at least some of the users. This is derived from numerous reports from CIUs (see chapter 3), which state that it is easier to perceive and recognise music that was known before the onset of deafness or prior to implantation.

The idea of melodic repetition is a simple but effective way in which melody has been approached for the purposes of this composition. Again, drawing from information gained from CIUs in the questionnaire study (see chapter 3), many people report that, in order to be able to appreciate a piece of music, they have to listen to it a number of times each time becoming more comfortable with different musical elements, for example. With this in mind, and the common-sense notion that familiarity can be gained through repetition, melodic content is often presented in a way that makes use of repetition in an interesting and supportive way. Figure 6.5 shows a lead sheet reduction for the introduction to the piece ‘These Fools Will Never Know’ (See appendix G, for the full score) which is based on the traditional melody of ‘Green Grow the Rashes, O’ by Robert Burns.

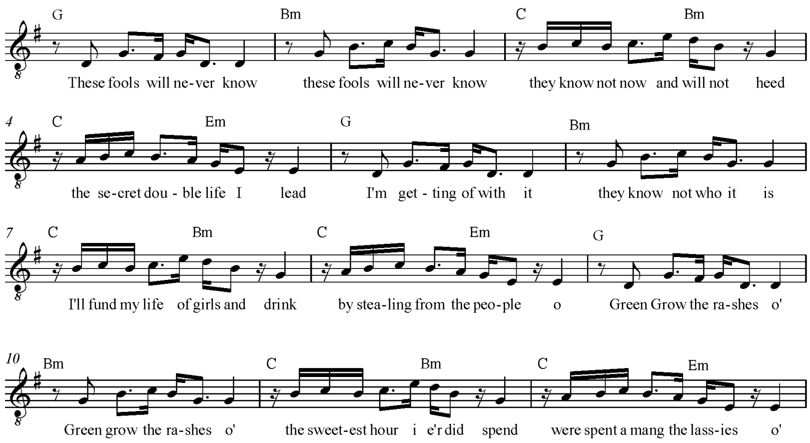



Figure 6.5: Melodic Repetition Example

The melody is based on a four bar repeating phrase taken from the chorus melody of the Burns song (see last 4 bars of the example for the original melody/lyrics). In this example, the first eight bars show new lyrics that are pertinent to the context of the story, and the following four bars show the original lyrics (which are repeated many times throughout the show). The inclusion of the original lyrics, although thematically relevant to the show also serves to provide a cultural framework and an acknowledgement of the original use of the melody, something which may be particularly useful for those who may find it difficult to engage with melodic or spectral components of the music. By using this repeating phrase, rather than drawing on the song in its entirety, it was intended that the melody would become familiar (another reason for selecting such a well known melody) to CIUs earlier in the piece and thus serve as a secure melodic foundation to progress from.

The third way in which the idea of melody was treated in this composition relates to attempts to foreground salient melodic information. Based on anecdotal evidence and responses from the questionnaire study (see chapter 3), it seems that there are a number of ways in which this can be approached. The two main ways used to create a distinction between main melodic content and other concurrent material were, the use of contrasting dynamics and timbres; and the setting of melodic information carefully within the musical setting. The use of contrasting dynamics and timbres is an obvious issue and is present in almost all elements of the music. If there is an important melodic element then this is always highlighted by way of instructing that it is either played at a louder volume or in a different range from the rest of the material. All the performers and sound engineers involved in the production of both the live performances and the AV recordings were informed of this important feature of the music and instructed to adhere to it in their performances.

Figure 6.6 is an example, taken from the piece 'Ceilidh' (see appendix G, for full score) of a sympathetic setting of melodic content:

As can be seen from the example above, in order to foreground this melody the backings are in the form of rhythmic 'hits'. This allows for listeners to attend to the melody (one which is particularly well known due to its association with the 'Gay Gordons' dance) without the rest of the band obscuring it.[3] When the rest of the band does play during this section of the music, they provide rhythmic support by accenting the melody in a way that is intended to provide momentum and rhythmic interest.

As was noted above, the concept of melody and its relationship with pitch is one that presents something of a contentious issue with regard to the perception of CIUs. The melodic components of this composition have been approached in a way that aims to maximise the potential for accurate and enjoyable perception of such elements.

[3]The 'Gay Gordons' (referring to the Gordon Highlanders, a Scottish regiment of the British Army) is a very popular Scottish traditional partner dance. It is a very common dance (due to it's simple repetitive nature) in which each couple performs the same steps, in a circle around the room. Again, due to it's simple nature, this is often danced at ceilidhs and other social events to the melodic example in figure **??**


Figure 6.6: Sympathetic Melodic Setting

## 6.6 Chords and Harmonic Elements of the Music

In the opening to the prelude the melody is a very simple ‘folk-esque’ diatonic melody in G major played twice by the saxophone, accompanied by the bass for the first time and by both the bass and cello the second time. As this is the first music heard in the ‘musical’, my intention was to create a musical situation that (according to the criteria noted above) favoured low pitches, texturally sparse arrangement and a simple presentation of the harmonic structure of the music. By playing the root of each chord, the bass provides a very simple outline of the root movement of the music and does so in a range that does not interfere with the presentation of the melody and implied harmony, something that is also clearly provided by the saxophone melody. When repeated, the saxophone and bass are joined by the cello, which serves the dual purpose of contributing to the melodic and harmonic facets of the music. Consider figure 6.7 below:

As we can see, the cello adds an additional layer of complexity to the music but does so in a way that is appropriate for the musical context and to the overall aims of this section of the show. The nature of the cello’s contribution is a combination of the roles of the saxophone and bass parts, such that it provides both counter-melodic and harmonic material. At many points, the cello line is used to harmonise with the bass in fourths,

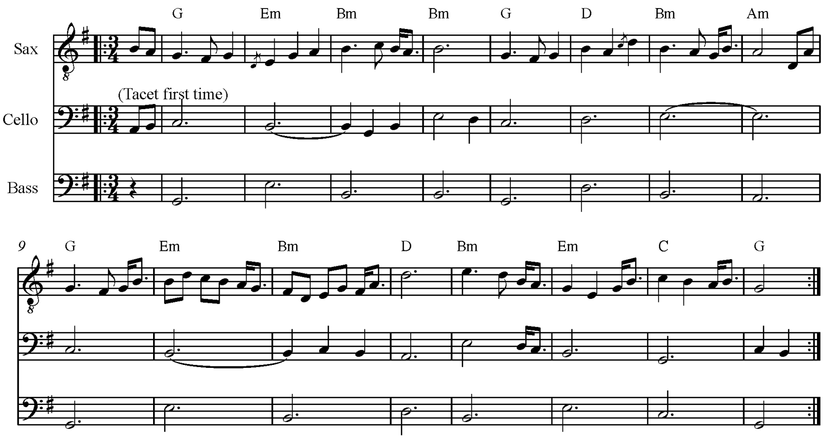



Figure 6.7: Harmonic Context Example

providing the effect (i.e. not functionally) of quartal harmony in some sections. This was approached in this way so that the combined sound of the cello and bass was less dense than if harmonised in thirds and, therefore, less likely to dominate and obscure the sound of the saxophone melody, given the common pitch area occupied at this point. In addition, such a relationship between the bass and cello lines allows for each instrument to be heard more distinctly due to the ‘open’ or ‘bare’ nature of the perfect fourth interval.

In chapter 3, one of the most common responses from participants with regard to their post-implantation music listening choices was ‘pipe-band music’. As has been discussed, there is a presumed cultural connection between such reports and the fact that this survey took place in Scotland, something which is extremely pertinent and interesting with regard to the musical experiences of CIUs. From a musical point of view, however, this is also very interesting when we consider the typical characteristics of this type of music. Pipe-bands typically consist of a large number of bag-pipers and a drum corps playing a combination of side-drum (snare), tenor and bass drum. Each piper will typically play pipes with three drones, two of which playing identical notes and one playing the same note an octave lower. The lowest of the drones is two octaves lower than the equivalent note on the chanter. Therefore, the pipers in this situation will generally create a sound that has a prominent drone doubled in octaves and any melodic component provided by the chanter will be at least two octaves higher than the lowest of the drones. It is presumed that this sound is reported to be successfully perceived by many CIUs because of the separation between the harmonic component (provided by the drones) and the melodic element of the music (provided by the chanter). In addition, the presence of a number of drummers playing various layers of prominent, interrelated rhythmic structures provides elements that are hypothesised to be successfully perceived by CIUs, according to research and anecdotal evidence.

With these issues in mind, a short (although, recurring) section of music was composed to emulate the sounds of the bagpipes, played by the bass and the saxophone; see figure 6.8:

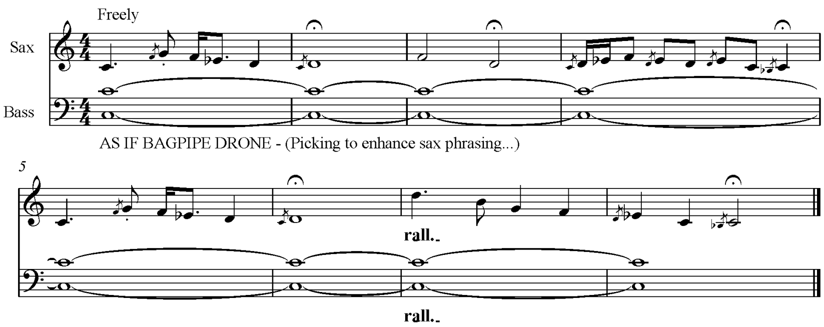



Figure 6.8: Harmonic Drone Example

As can be seen from figure 6.8 which is taken from the piece ‘Turning King’s Evidence’ (see appendix G, for full score), the bass guitar was used to suggest the sound of the bagpipe drones with long-notes doubled in octaves. As the strings of a bass guitar obviously has far less sustain than bagpipe-drones, the note are required to be re-picked, however, this was instructed to be performed in accordance with the phrasing of the saxophone. The saxophone melody is a variation on the main melody from this piece and is played as a pibroch style dirge, with ornamentation used to imitate the sound and playing styles of the highland pipes in this type of music.[4] The melody is in the key of C minor and the bass is used to provide a pedal of the tonic.

The harmonic perception of CIUs is not an issue that is discussed in the literature in this area and not an issue that has been raised explicitly in any of my discussions with CIUs or in the MEQ study (see chapter 3). However, the fact that such issues are inextricably bound to notions of pitch, spectra, and timbre, for example suggests that this is a pertinent area that should be considered when thinking about the creation, manipulation or analysis of music in this context. Issues such as those discussed above are examples of some of the ways in which elements of harmony may be approached in order to maximise the potential for a positive experience of this musical element.

[4] Pibroch is a musical form originating in the Scottish Highlands, often associated with repeating melodic content and improvised variations and is usually played on bagpipes (both bellow and bag driven) the fiddle and the clarsach.

## 6.7 Timbre and Textural Elements of the Music

When referring to timbre in this context, I include the sound of individual instruments and the timbre of the sound produce by an entire ensemble and intra-ensemble instrumental combinations. During conversations and interviews with CIUs it has been mentioned that a timbral distinction between the primary instrument and those providing backings, leads to improved perception and a better listening experience. In connection with this, it has also been stated that a difference in volume between the primary instrument or vocal and the backing or the rest of the band also has a positive effect as it becomes easier to focus on the sound and musical information presented by this instrument/vocalist. This can be considered in terms of signal-to-noise ratios in the sense that, for the CI system, which has been designed to process speech, the speakers voice is the important signal and ambient and background sounds, by their very nature, can be classed as noise.[5]

With the two latter issues in mind, we can consider the following hypothetical but relevant musical example; in a group consisting of drums, bass, two guitars and a vocalist it could be argued that, although it is the combined sound of the aforementioned instruments that people will hear, the singer is presumably the element that most people will be focusing on. As a result (for CIUs) the singer in this case, could be considered to be the signal, with the rest of the band creating what could considered as noise (to continue with the signal-to-noise analogy). This relationship may change throughout the duration of the music, in the case of a guitar solo, for example, where the sound of the guitar becomes the most salient element, temporarily. Regardless of the details, if the focus of the music (be that a singer or a guitar solo, for instance) is too close, in terms of timbre or volume, to the rest of the ensemble, then this may cause problems for many users who may have difficulties in focusing on important elements as a result; something which may lead to negative music listening experiences. Incidentally, this may also be one of the reasons for CIUs stating that they often prefer the sound of older pop music to contemporary pop music (see chapter 3), which is often characterised by less distinction between the vocals and the backings, if this distinction is even appropriate such as in some commercial dance music, for example. Although this is a simplistic view and one that tends to consider music in a modular or compartmental sense, it is important to illustrate that many CIUs comment on issues in this way. This is illustrated in many of

[5] Galvin (2009) showed that CIUs display great difficulty in perceiving melodic contours in the presence of a competing simultaneous instrument 'masker' due to reduced access to timbre cues used to distinguish instrumental sounds.

the views presented chapter 2 and is one of the main reasons for the development of the mixer application (see chapters 4 & 5).

Another very interesting observation from a smaller number of CIUs was that this idea of separation between primary and backing instruments for example, is also relevant to an extent, for frequency. Some people notice that if multiple primary instruments are sounding simultaneously, that this is more frequently well perceived if they occupy different areas of the spectrum. One example given was that if there is a male singer and an electric guitar playing together, it is easier to distinguish and understand each instrument if the singer is performing low-pitched, and the guitar playing high-pitched material. It was also pointed out that the same idea applies when the singer is performing high-pitched material, in that this allows for the other instruments, bass and drums etc. to be heard more clearly. From this it seems obvious, therefore, that instruments (for various different reasons) can have a making effect on one and other for CIUs. Additionally, instruments can have very different timbral qualities across their pitch and volume ranges.

In relation to the information presented above, with regard to the texture of the music, and considering the processing strengths of the CI system, it may be hypothesised that texturally dense material may be problematic to perceive and may, as a result, lead to confusion, distortion or other unpleasant music listening (perceptual) experiences. The more dense the material, the more likely it is for the music in it's totality to be perceived as noise. From personal interviews and data gained from questionnaires (see chapter 3), it has been noted that many CIUs report a preference for music that is performed by *small* groups, with people frequently making the interesting exception of pipe band music (which are large ensembles by their nature).

Figure 6.9 is a graphic performance plan representing the form of the piece 'If I'm Honest' which features only the rhythm section and the vocalist. Vertical columns represent the different sections of the song, progressing from the introduction (at the left) to the coda (at the right). The horizontal rows represent the contribution of each of the instruments throughout time. Patterned space represents points at which the instruments are playing and blank white space represents silence for that instrument. In addition, the density of patterning in the representation relates to the density of the material being performed in the corresponding section of the music.

As can be seen from figure 6.9, the introduction is played by a solo guitar, which is joined by the vocals for the verse. During the bridge the guitar changes from a

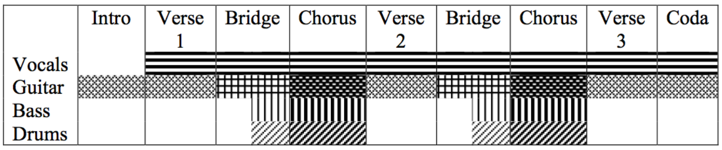



Figure 6.9: Texture Performance Plan

finger-picking style to a (lightly) palm-muted strumming style which provides more definite rhythmic cues. In the second half of the bridge, the bass and drums join the guitar and vocals; both of which play very lightly and steadily, thus adding to the rhythmic feel that builds during this section. During the chorus all four parts play, meaning that the arrangement becomes more full and dense. This said, the vocal line changes in character to allow it to remain the primary focus of the music, such that melodic line becomes higher pitched with longer phrasing and more sustained notes. During the chorus, the bass starts to move away from the role of simply outlining the root movement and begins to add melodic fills. The verse, bridge, chorus form is then repeated before the final verse and coda, which are performed by the vocals and the finger-picked guitar, in a similar manner to the introduction and first verse. Figure 6.10 shows the score for the chorus:


Figure 6.10: Chorus Arrangement Example

This type of arrangement is one that could work particularly well with CIUs due to the incremental increase in the instrumentation and complexity of the music (and repeated forms). By having the solo guitar start the song and the vocalist entering slightly later means that listeners have time to become used to the sounds before they become more complex. This is also true of the bridge where the guitar playing technique changes slightly before the bass and drums enter very lightly. A bass glissando and drum fill into the chorus suggests that the music is going to change again and this expectation is fulfilled in the chorus when the full band is playing (see figure A, above). The repetition of this form provides the listener with a second opportunity to experience this gradual increase in complexity in the hope that the listener has become comfortable with the sounds of the individual instruments, the combinations of such and the way in which these change as the song progresses.

## 6.8 Cultural Elements

In general, the points above relate specifically to musical issues surrounding the way in which music is structured temporally, spectrally or melodically. Another important consideration when composing this music was the way in which the music relates to people socially and culturally. This is particularly important with regard to the third category of the framework for musical experience outlined in chapter 1 i.e. social/environmental experience.

As discussed above this music was composed as a 'musical', which tells the famous story of 'Deacon Brodie'. The theatrical nature of the storyline and production (e.g. animations and projections, see appendix H), coupled with the inclusion of familiar traditional Scottish melodies were intended to facilitate comprehension by providing a coherent cultural context. In setting this well-known story to (largely) culturally appropriate music, I believed that this would build on the idea of creating a narrative framework by also creating a recognisable cultural context. Drawing on recognisable references to musical culture and tradition was thought to be an appropriate way to maximise the potential for positive musical experiences due to many reports from CIUs suggesting that 'familiar' music is often well perceived (see chapter 3).

## 6.9 Appraisal by CIUs

### 6.9.1 The Questionnaire

Geoff Plant (on behalf of MED-EL UK, the commissioners of the 'Deacon') conducted a questionnaire survey of the audience and I have been given full access to the results. The following is a summary of the conflated findings from three performances.

### 6.9.2 Participants

Participants were 22 cochlear implant users (Female = 13, Male = 9) aged between 16 and 74 years old (mean = 53.6). The participants comprised of 8 left-ear CIUs, 12 were right-ear CIUs, 1 bilateral CIU and 1 participant who failed to provide this information.

The musical background of this sample was investigated and, when asked how often they listened to music (by means of a seven-point likert-style item) the average rating was approximately 4 (4.1[sic.]), which corresponds to a qualitative rating of 'sometimes', as per Plant's Questionnaire. 2 of the participants stated that they play a musical instrument, 16 state that they do not and 6 indicated that they used to but do not do so anymore, as a result of their cochlear implant. When asked 'do you like to sing?', 10 participants say that they do, 5 say that they do not and 6 state that they used to but do not any more  again, 1 participant failed to answer this question.

### 6.9.3 Results

Participants were asked to provide an overall rating of the music by way of a seven-point (likert-style) scale ranging from 'terrible' to 'excellent'. Although Plant's original data made use of mean values, where possible, this data has been re-analysed in order to find and report the modal value which is more suitable for the analysis of data garnered from such scales. The mode for this question was 6 (range 3-7), which corresponded to a qualitative statement of 'Very Good' on the original scale. The same scale was used to gauge the impression of the overall sound of the music and, again, the mode was 6 (range 3-7), corresponding to 'Very Good'. When asked 'which word best describes your reaction to the music?', the sample show a mode of 5 (range 3-7) on the same scale which corresponds to a rating of 'Good'; however, on this question one participant failed to answer.

In addition to questioning the participants' general or overall impression of the music and sound, their reactions to individual instruments were also probed using the same scale. Results are presented in table 6.3 below:

| Instrument | Mode | Range | Qualitative Rating |
|---|---|---|---|
| Acoustic Guitar | 4 | 3-7 | Acceptable |
| Cello | 5 | 4-7 | Good |
| Bass Guitar | 5 | 3-7 | Good |
| Percussion | 5 | 3-7 | Good |
| Saxophone [6] | 6 | 3-7 | Very Good |
| Singer | 4 | 3-7 | Acceptable |

Table 6.3: Instrumental Sound Ratings

Table 6.3 shows that the saxophone had the highest mode, which corresponded to a rating of 'Very Good' (range 3-7) on the original scale. However, the responses for the cello show a mode, which corresponds to a rating of 'Good' on the original scale but shows a smaller range (4-7).

When asked 'Would you like to attend any future musical events aimed at listeners with cochlear implants?', 21 participants said yes and 1 participant said no. Comments from the performances are presented in appendix F, in order to illustrate the qualitative responses from the audience. An outline of these results are presented below:

An important theme raised by a number of participants in their feedback was the issue of expectation, something which relates (as discussed above, also see chapter 1) to the cognitive experience. One participant stated that the music sounded better than they had expected and that they have very low expectations for the implant-mediated sound of music. Another user commented on expectation with regard to the musical content and stated that "...it is easier to follow the music if one is familiar with the song before deafness.". Again, this was an important consideration in the composition of the music with regard to the cognitive experience.

With regard to the orchestration, one participant noted that their "...enjoyment of listening to a given instrument was maximised when there were little other instruments playing...". This is an issue that is understandable based on conversations with CIUs during my internship at the HRF (see chapter 2) and results from the MEQ (see chapter 3) and highlights the considerations outlined above with regard to the timbre/orchestration of the music. Interestingly, the same participant reported: '...I don't know if it's due to personal preference but when instruments increased their pitch I enjoyed it much more.". This is contrary to the majority of reports from participants who attended the music focus group and the MEQ (see chapters 2 and 3, respectively), however, it is particularly important as it highlights the individual variability and range of music preferences of CIUs.[7]

Audience responses were generally positive and many people report pleasure regarding the musical experience or the actual music itself. One participant notes; "This is my first musical night since my cochlear implant and it is such a pleasure and a joy to be re-introduced to live music again. To be able to follow the beat and hear the change in turn and the various instruments was an absolute pleasure. Thank you so much for giving it back to me.". This is a particularly useful comment as it mot only mentions the positive nature of the general musical experience but also refers to the sensory experience in relation to the musical elements. The social/environmental experience is also alluded to when he/she states their joy at being re-introduced to live music.

Participants also talk about the fact that they would like to have future opportunities to listen to/watch this 'musical', including a participant who states that they; "...will appreciate the DVD and look forward to watching it again" and another who would like a CD of in order to be able to put it on their iPod. Another participant noted that this was his/her "...first venture listening to music since implant..." and that they look forward to listening to more.

Feedback from users commented on the nature of the performance and presentation and also provided some suggestions for future performance including the idea that it would be beneficial to "...employ a cursor on the song lyrics..." and a "...spotlight on singer..." both of which are suggested as ways to improve comprehension of the lyrics. It was also noted by one participant that the performance was too loud.

These findings have been included by way of illustrating some qualitative feedback that has been gained as a result of public performances of this 'musical'. It should also be reiterated that the results are from questionnaires administered at performances of the work and results are therefore, undoubtedly influenced by specific circumstances (not to mention personal and social issues) surrounding the performance such as the front-of-house mix, the view of the stage and musicians, the ability to see the

[7]Responses of this nature provide further support for the value of individualised approach to musical experience, such as the mixer, for example (see chapters 4 and 5).

projections, for example.

One of the most important things to draw attention to in this data, with regard to musical experiences is the fact that there is, inevitably, variability in the responses of participants with regard to many issues. Such issues include the relative qualitative ratings of instrumental sounds or the overall sound, for example. However, every participant except one stated that they would like to attend future musical events aimed specifically at CIUs. Regardless of the way in which the music described in this chapter was perceived, the fact that the vast majority of the audience would like to attend similar future events shows that this project was, in many ways, a success. If this work has interested CIUs in music and encourages the pursuit of musical experience then this is an important contribution to the field of cochlear implants and music and one that goes beyond simply demarcating the perception of disparate musical/structural elements and commenting on the efficacy of the implant system, and by extension, the implanted person's ability to engage with such elements.

The fact that participants rated the music reasonably favourably is encouraging and extremely interesting, but this investigation probes the responses of audience members to live performances and therefore incorporates all three of the categories which I propose inform musical experience, at least for the purposes of this thesis (see above and chapter 1 for more details). In many ways it was extremely important, due to the involvement of real people, engaging in a process of genuine 'musicing' and reflecting on it based on their understanding of musical experience.

## 6.10 Conclusions

This chapter has described the way in which information relating CIUs' perception and experiences of musical elements has been utilised in order to create a composition, specifically created to appeal to their music listening needs. Throughout this chapter and indeed, this thesis, attention has been given to the way in which the issue of musical experience has been dealt with and I believe the work outlined in the current chapter deals with issues that relate to each of the three categories proposed (above) to inform musical experience. This is particularly obvious with regard to the first of the three categories, sensory experience such that examples of the way in which elements such as instrumentation, rhythm, pitch, melody, timbre, orchestration, at texture, for example, contribute to and can be utilised by way of creating a composition of this nature have been presented. These elements, and the way in which they are perceived by CIUs, plays a large part in the analysis and evaluation of musical experience.

With regard to cognitive experience (i.e. the second category in this framework), it was stated in chapter 1 that music cognition is a field that attempts to understand the various mental processes that enable interactions with music; issues such as perception, memory, attention and emotion were presented as examples of such processes. With this in mind, in conceiving of cognitive experience as one of the categories that contribute to musical experience, I believe that the work outlined in this chapter is strongly related to such issues. To quote Dowling and Harwood (1986, p4), again:

'Sensations are filtered through perceptual processes that direct attention to important events…Musical sounds and the musical actions of others are environmental stimuli that are important…sensed by our ears and eyes and interpreted in the context of our memories.'.

In light of this we can consider that a great deal of this work relates to the way in which the cognitive experience is appealed to and manipulated in order to positively inform the general musical experience. Ideas such as the inclusion of familiar melodies, the repetition of musical material and the setting within a narrative and cultural framework, for example, were intended to appeal to the previous experience and memories of the audience. This is also linked to the suggestions from CIUs that familiar material (often from before deafness/implantation) is often most successfully perceived. In addition, presenting this work in an audio-visual manner invokes a multi-sensory experience. This is particularly important as visual aspects of the performance (or DVD recording) can assist the perception of the music, for example, seeing instruments played can inform people of the source of a potentially problematic stimuli.

The third category in the framework set out for musical experience relates to social and environmental experience. I believe that this facet of experience is one that is widely addressed by the creation and performance of this 'musical'. As discussed in chapter 1, the social functions/effects/experiences of music, or 'musicing' (to adopt terminology which fits the approach of this thesis more appropriately) are too numerous to address entirely. In fact, such an aim is not the objective in this context, however, the intention to consider such social experience as a contributing and influencing factor of musical experience is particularly important. With regard to the composition of the music outlined in this chapter it is obvious that the issues relating to sensory and cognitive experience are in many ways more prominent than the social/environmental experience since they ostensibly impinge more on the issues that seem to surround discussions of the music listening or music perception abilities of CIUs.

However, CIUs who attended any of the performances of this ‘musical’ and those who have chosen to watch it on DVD or listen to the CD version are engaging in a genuine process of ‘musicing’ and thus cannot experience it out-with a social or environmental context. The social/environmental experience linked to this music and the experiential benefits that can be garnered from such an activity (e.g. the ritual of concert-going, having a shared musical experience with friends/family) are particularly relevant in this context; see chapter 1 for a detailed discussion of such issues and the way in which they may impact on musical experience. In addition, the fact that CIUs are aware that this music has been specifically composed for people with cochlear implants (and that the audience, or listening at home, comprises many other people in a similar position to themselves) may add to the social experience and impact favourably on the evaluation of the musical experience.

# Chapter 7

# Conclusions

This chapter will present general conclusions that can be drawn from this research and will do so based on each of the three main sections of the thesis. Additionally, an outline of the limitations of this work and possible directions for future research will also be presented.

## 7.1 Musical Experience

This thesis began by reviewing current literature in the research area of cochlear implants and music, and drew the conclusion that the vast majority of such research is primarily focussed on issues relating to the music perception abilities of the CI system and, in turn CIUs. Although this research is extremely valuable to the field, I believe that by focussing mostly on perception, a number of other important issues related to music and the way in which people engage with, understand and enjoy it can be neglected. This, coupled with contact with many CIUs, either in person or via responses to the MEQ study (see chapter 3) strengthened my belief that perception was not the only relevant factor in people's engagement with music and that many other issues also contribute and inform people's enjoyment or understanding of music, for example. Therefore, it was decided that it the focus of this research would be on the *musical experience* of CIUs.

For the purpose of this thesis, it was suggested that a suitable framework for the consideration of musical experience in this context was a categorisation of potential issues consisting of three separate areas. The first of the three categories was defined as sensory experience which relates to perceptual awareness/experience, for example, the awareness of sensory input in relation to the formal/structural elements of stimuli. The second area was defined as cognitive experience which relates to Internal/mental awareness/experience, i.e. the interpretation of sounds as musical events, based on cognitive factors such as expectation, association or emotional connection, for example and additionally, in relation to the research area of embodied music cognition which also includes the inter-relationship of the mind, the body and the physical environment in the approach to (and understanding of) musical experience. The third area was defined as Social/environmental experience which pertains to external awareness/experience such as social and cultural factors surrounding the music or the experience of music within such contexts and physical environments.

By approaching this research with such a framework in mind, it has been possible to include the consideration of issues such as the participant's history or deafness and previous musical experience, or their tastes and preferences and personal connections to music. This has led to rich data which allows us to consider participants as human-beings who use a cochlear implant which may influence or impact on their experience of music in many ways, rather than viewing participants simply as experimental subjects who's personality, background and experience is ignored, or perhaps even controlled for in experimental design, for example. Although this type of research is important as it has built a body of knowledge relating to CIs and music and may have considerable implications for the future of CI design/development, for example, it's focus does not addresses the nature of music and peoples' experiences of/with it, hence the specific focus on *musical experience* within *this* thesis.

Considering the focus of the research in this way is one of the most important conclusions to draw attention to as it is fundamentally relevant to the way in which this research has been conceived, structured, executed and analysed; and, therefore, impacts on all areas of the work. Such a focus is what I believe separates this research from the majority of other work in this area and makes an original contribution to the field.

## 7.2 Investigations of the Musical Experiences of CIUs

The first section of the thesis outlined a number of ways in which the musical experiences of CIUs were investigated/surveyed as a direct reaction to the fact that the previous research, although extremely important to the field of CIs and music, was believed to focus primarily on music perception rather than the exploration of musical experience. Based on findings and results from this section of the thesis which show that, although there is a great deal of variability in the musical experiences of CIUs, many people report positive experiences of music despite what may be described as ‘poor music perception’, a number of important conclusions can be drawn.

Firstly, it is extremely important to draw attention to the fact that an important finding of this research is that ‘music’, in the most general sense, is something which is very important to many CIUs and the enjoyment of music is something that many people place an enormous amount of value in. This is consistent with a great deal of anecdotal evidence and something which should not be overlooked. Partly as a result of the importance that most people place on music, the implant-mediated relationship with music can be particularly complex, drawing on a number of factors; hence the importance of the framework for musical experience, as outlined above. A great deal of current research shows that the music perception abilities of CIUs are largely ‘inferior’ to those of NH control subjects for most musical elements, however, although this may be the case for many CIUs, their musical experience is not defined by this. Put simply, the relationship between music perception and musical experience is not simply that poor perception equals poor experience. Firstly, it is important to remember that musical experience is a complex coalescence of many factors, not simply the sensory experience. Secondly, and perhaps most importantly, the idea of 'poor' perception is a subjective notion that has little validity when applied to the question of musical experience.

The fact that the musical experience is highly subjective and individualised is another important conclusion to be drawn from this first section of the thesis. In the MEQ study (see chapter 3) analysis of the data yielded three sub-groups relating to the history of the participants deafness, specifically: the congenitally deaf group, the pre-adolescent group and the late-deafened group.

A finding from the MEQ study (see chapter 3) shows, when considering the frequency with which participants *chose* to listen to music, that their history of deafness has a strong effect on this, and in turn their experiences of music, such that the late-deafened group choose to listen to music significantly less frequently post-implantation and the congenitally deaf group choose to listen significantly more frequently post-implantation. This is one particularly strong finding as a result of this study which exemplifies the way in which the musical experience is subjective in that a group of people with very different backgrounds have very different responses to music based on their prior experience. It was believed from the outset of this work that musical experience is an *individual* phenomenon which may have categorisable similarities among groups, for example, but that is shaped and influenced by the experiences of individuals and this finding supports this original belief.

The study of group differences was also very important in this thesis as it raised some interesting results with regard to the nature of CI-mediated music listening. However, due to variability amongst individuals, musical experience (as outlined by the three categories, above) should be considered as a personal, individual and subject-centred issue with no value-judgement placed on that of one person, or group of people, over another. In other words, the musical experience is a product of the interaction of a person *and* music, thus, the musicking person is the only person adequately qualified to comment on the value of the various facets of *their individual* musical experience.

## 7.3 Multi-channel Mixer

The second section of the thesis detailed the design, development and implementation of the multi-channel mixer application which was used in a study exploring the way in which CIUs mix multi-channel music, to gain insight into their experience of musical sound and structural elements of music. By analysing the user-generated mix data, it is apparent that there is a large degree of variability amongst CIUs, and also that the average mixes of CIUs differs significantly from those of a control group of normal-hearing (NH) participants.

Results show that, when given the opportunity to manipulate the sound of multi-channel music using the mixer application designed for this study, there is a degree of variability amongst participants (particularly the CIUs) with regard to the LTAS of these mixes which is a result of the variability in the instruments chosen to be included in mixes and the way in which the sound of these instruments have been affected. Despite this variability, user feedback shows that the mixer was unanimously regarded as useful tool for the improvement of musical experience. This study also shows that the average mixes of CIUs and of NHs are significantly different thus demonstrating that these groups have significantly different listening preference/needs, something which is particularly important to consider when aiming to develop strategies for the improvement of the musical experiences of CIUs. Additionally, the CIU group believe that the use of this application improved their musical experience as it afforded them a degree of control over their sensory experience of the music so that they could tailor it to their own listening needs.

The development of this application and it's use with CIUs in this way has provided results that are an original contribution to the field of 'CIs and music' as this has provided experimental evidence to show that there is a significant difference between CIUs and NHs with regard to the LTAS of multi-channel music, the number of audible channels included in a mix and the EQ of various instruments within the mix. These findings have direct implications for the composition, mix and production of music for CIUs but, more importantly, the mixer system and the benefits it has for *individuals* (according to their feedback) to manipulate the way that music sounds to *them* could be used as a valuable element in a music (re)habilitation program.

Based on results from this section (specifically, the variability of the results in the CIU group) another important conclusion is that, where possible, attempts to improve the musical experiences of CIUs should be as individualised as possible. Therefore, systems which offer the ability for CIUs to engage personally with music and alter/manipulate it in a way that suits them should be favoured. The variability of experience and perceptual ability amongst CIUs means that any attempt to create a 'one-size-fits-all' solution for the improvement of musical experience, particularly with regard to the sensory experience of music, would be problematic at best.

The mixer application could be a valuable part of a rehabilitation strategy (see below), however, it doesn't account for the communal listening experiences of concerts, for example and I believe that this remains something that is important to work towards (i.e. specialised composition).

## 7.4 Performances of Specialised Compositions for CIUs

The third section described the composition and evaluation of a musical work specifically composed for CIUs but designed to be enjoyable for both CIUs and NH audience members alike. The aim of this composition was to promote a positive musical experience by addressing elements of the sensory, cognitive and social/environmental experience based on findings of this research and the existing literature and it is possible to draw two main conclusions from this section of the thesis.

Firstly, the composition of specialised music for CIUs is a particularly effective way to provide stimulation for each of the three areas of musical experience as detailed in chapter 1 and outlined above. The composer can draw on research such as that which is presented in this thesis (see appendix G) for the scores and appendix H) to develop the composition so that it is sympathetic to musical elements or styles, for example which are most suitable to the audience. In doing so, the composer is largely dealing with the sensory experience and aiming to create music which will provide a positive sensory experience for the majority of the audience. The cognitive experience can be appealed to in a number of ways, however, one obvious example would be that the composer can choose to draw on musical elements/techniques or even melodies/styles, for example, which may be familiar to the audience in an attempt to provide a positive cognitive experience (the joy of recognising familiar music, for instance). Although these are simple ideas and only scratch the surface of the way in which a composer may be able to appeal to the various facets of musical experience, it is important to realise that the process of specialised composition for audiences of this nature allows for issues such as this to be addressed and manipulated by way of improving the musical experience.

Secondly the live performance of music, particularly that which is specifically composed for CIUs is a particularly important and dynamic experience. Interestingly in this case, the individualisation of the experience is not the primary objective as is the case in the mixer study (above), for instance. Although it is suggested below that future research may see the mixer application integrated into live music experiences, in the mean time, live concert situations are excellent ways to generate and promote positive communal social/environmental musical experiences. As was outlined in chapters 1 and 6 there are many elements of the concert experience which influence the general musical experience despite not being directly related to the music, such as the thrill and ceremony of concert-going, social interaction or being in interesting or stimulating physical environments (concert halls, theatres, clubs), for example. Therefore, this type of activity should be actively encouraged for CIUs by way of improving the musical experience as the subject is susceptible to a wide variety of stimuli (other than the actual music) and situations which are also likely to inform the musical experience.

## 7.5 Limits of the Research

The research detailed in this thesis is, inevitably, subject to a number of limitations in process and in scope which should be acknowledged at this point. Firstly, the original research detailed in this thesis was conducted by a single, individual researcher (unless otherwise stated, as in chapter 2, for example) and with considerable time and funding constraints. Additionally, as was highlighted in chapter 5 there were a number of issues which meant that access to experimental participants was problematic such as patient/client confidentiality in the case of the NHS and Deaf Connections, for example. Additionally, the fact that eligible participants are widely geographically dispersed meant that it was very difficult to gather large numbers of participants together simultaneously. This is one of the reasons why a questionnaire study was so successful as in the MEQ study (chapter 3), i.e. participants did not need to travel but were able to submit their responses remotely by post or via an online version of the questionnaire.

Although as noted in chapter 5 the eventual number of participants was of detriment to the study or the results gained from it, it is important to acknowledge that the recruitment process was difficult for this reason. Additionally, more participants may have facilitated further investigations such as intra-group analyses for example. Although every possible effort to recruit participants within the limits of the aforementioned time and funding restrictions, the eventual number of participants in the mixer study (8-experimental + 8-control) meant that this type of analysis was difficult and although sub-groups can be created within the experimental group, the very small number of participants in each renders such analyses impractical. Future studies of this nature should be aware of this and aim to recruit as many participants as possible.

## 7.6 Suggestions for Future Research

There are two main points that I feel are important to consider for future research in this area. Firstly, that investigations in this area should consider the idea of musical experience so that research remains subject-centred and does not become overly objective or concerned with the processes and efficacy of perception. This may lead to a situation in which the subject's experiences are neglected and the nature of 'music' with regard to the stimuli becomes questionable. Secondly, that where possible, the improvement of musical experiences should be as individualised as is appropriate in the long term; systems such as the mixer application developed for this thesis will be helpful in such endeavours.

With regard to the mixer application, I suggest that a number of developments would be beneficial so that it may become a useful tool in the improvement of the musical experiences of CIUs; specifically, one development which could be particularly useful is as follows. A large corpus of musical stimuli could be created to reflect a wide range of styles which users mix in the same way as described in this thesis. Over time, a ‘mix-profile’ would be generated for each user which reflects their *individual* treatment of the various styles represented by the stimuli and can be used to generate E.Q. presets. These E.Q. presets can be used in conjunction with normal, commercially released music by way of attempting to improve the sound of recorded music which is obviously not designed to be used with the mixer application. Although users will not have as much control over the musical elements as they do in the multi-channel mixer environment, this may be a useful way to improve the musical experience of recorded music for some CIUs.

Additionally, with regard to the sound of live music, it would be possible to develop the mixer application so that it was capable of receiving multi-channel streams of music data from live performances. If, in a concert situation, the output of each channel of the mixing desk (rather than only the stereo-bus, as in most situations) was transmitted to the mixer application (ideally wirelessly), CIU audience members could conceivably engineer their own mix of the signals and enjoy a the concert in a way that suited them by selecting what they hear and the balance of signals. Again, data could be stored by the mixer, perhaps on a continual basis throughout the performance to allow more dynamic mixes, and collected for analysis after the performance.

Given that any such developments would inevitably take time to achieve and refine and would depend on technology and the ability of the audience to engage with this, it seems obvious that another option for providing musical experiences without the use of the aforementioned technologies is the composition of more specialised compositions. This, although more general and less individualised by it’s very nature, could be an effective way of promoting positive musical experiences and could do so for each of the categories of experience as discussed in this thesis.

As this area of research is in it's early stages I believe that there is a great deal of work required in order to develop strategies and methodologies that will aid the development/improvement of musical experiences for CIUs. Expertise from different disciplines and areas should be welcomed gratefully and a multifaceted approach should be taken in order to develop knowledge, technology and compositions that may be instrumental in this objective. However, I strongly believe that *music*, in the most general sense, and the consideration of subject-centred approaches to musical experience should not be neglected in favour of research into music perception. Consideration of musical experience within the theoretical framework set forth earlier in this thesis (see chapter 1) may help to focus future research and avoid one element of the experience being favoured to the detriment of others which may contribute to the general experience of the music.

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# Appendix A

# Increasing Complexity Example

1. The melody played by one instrument, in this case played by the keyboard first then followed by the saxophone, separately.

2. The melody played in unison by both instruments (if the range of the instruments allow the part to be played in unison). For example, figure 1 (below), shows a melody written in unison, however, the tenor saxophone will sound an octave lower than it is written.


Figure A.1: Melody In Unison Octaves

3. The melody played as before with a second (lower) part, i.e. a bass line. In this case, where there were two instruments available, the keyboard could play the melody whilst accompanied by the saxophone playing a simple bass-line outlining ONLY the root movement of the harmonic progression (at this stage). Following this, the instrumentalists would swap parts so that the saxophone played the melody and the keyboard played a bass-line as an accompaniment. This allows for participants to hear the components of the music played by each instrument.


Figure A.2: Melody with Bass Line

4. The melody played, as above, with a bass-line that is more complex. This increased complexity is a result of more melodic interest in the bass-line due to other harmonically informed note choices other than the root of the chord. Also, increased rhythmic interest contributes to greater complexity in the music. Again, as above, each instrumentalist alternated between playing the melody and the bass-line.


Figure A.3: Melody with Developed Bass Line

5. The melody accompanied by chords outlining the harmony of the music and a simple bass-line outlining the root movement. In the case of the keyboard and saxophone the two options available to us, due to the saxophones incapability to accurately or practically provide a homophonic chordal backing, were; (a) for the saxophone to play the melody whilst the keyboard played the chords and the bass-line or; (b) for the saxophone to play the bass-line whilst the keyboard played the melody and the chords.


Figure A.4: Melody, simple bass-line and chords

6. Melody presented with a chordal accompaniment or bass-line more complex than the previous version. This increase in complexity could be achieved by the notes of the chords being arpeggiated rather than harmony being presented as block chords. Also, chords may be substituted, extended or altered in order to provide more harmonic variation or interest and may be played more rhythmically. As above, the bass-line can be made more complex by melodic interest in the bass-line as a result of note choices other than the root of the chord or other chord tones. Also, increased rhythmic interest will lead to greater complexity in the music (syncopation etc.).

7. Having explored some of the varied possibilities for making melodies more complex by providing accompaniments and, in turn, taking steps to increase the complexities of such accompaniments, the next stage may be to begin to alter the recognised


Figure A.5: Melody and more complex presentation of harmony

melody. One simple way to do this may be to add basic ornamentation such as grace notes (appoggiatura/acciaccatura), trills, turns, for example or to modify the phrasing of the melody by altering the duration of the notes or their accent or stress within the bar.


Figure A.6: Adapted Melody with More Complex Presentation of Harmony

8. In addition to simple melodic adjustments, the use of counter melodies (i.e. a sequence of notes that is played at the same time as the main melody, often perceived as a subordinate or less prominent melodic idea) will add yet another layer of complexity to the presentation of the music. As with all the stages noted above, this melody can be embellished and altered in a variety of ways in order to increase the complexity of the music. As a melody of this nature will inevitably create some harmony in the music, a further layer of complexity would be to construct a counter melody that creates interesting or unusual harmonies.


Figure A.7: Melody, Chords and Counter-Melody

# Appendix B

# Musical Experiences Questionnaire (MEQ)

INSTITUTE FOR MUSIC IN HUMAN AND SOCIAL DEVELOPMENT [IMHSD]

# Cochlear Implants and Music Questionnaire

This questionnaire has been designed to provide information about how your cochlear implant affects your music listening. Please answer all questions as fully as possible, providing as much information as you can. We estimate that this should take approximately 10 minutes to complete. Please note that this questionnaire is completely anonymous.

1. **First half of post-code (eg. EH11, G15 etc.):**____________________
(This will let us know where people with CIs live and will help us to plan future research.)

2. **Please enter the PASSWORD printed on your information letter:** ________________

3. **Gender** (circle as appropriate)**:** **MALE** **FEMALE**

4. **What age are you?** ______________________________

5. **What type of cochlear implant do you use** (circle as appropriate)**:**

**ADVANCED BIONICS** **MED-EL** **COCHLEAR**

6. **Do you know the model?**

________________________________________

6(b). **Do you know what processing strategy your implant system uses?** (circle as appropriate):

**CIS** **ACE** **SPEAK** **OTHER:** ____________________

7. **Which ear is implanted?** (circle as appropriate)**:**

**LEFT** **RIGHT** **BOTH**

8. **Are you left or right handed?** (circle as appropriate)**:**

**LEFT** **RIGHT** **AMBIDEXTROUS**

9. **Where were you implanted?** (circle as appropriate):

**KILMARNOCK** **EDINBURGH** **OTHER**

9(b). **If 'other', please give details:**____________________________

10. **Do you wear a hearing aid in the other (non-implanted) ear?** (circle as appropriate)**:**

**YES** **NO**

11. **How old were you when you became deaf?** ______________________

12. **Did you use hearing aid(s) before receiving your cochlear implant?**(circle as appropriate):

**YES** **NO**

13. **If 'yes', how old were you when you started wearing hearing aid(s)?**

________________________________________

14. **How old were you when you received your cochlear implant?**

________________________________________

**15.** **How much speech can you understand with your cochlear implant?**
(Tick **one** box as appropriate)

1 = None ☐
2 = Very Little ☐
3 = A little ☐
4 = About half ☐
5 = A lot ☐
6 = Almost all ☐
7 = Everything ☐

**16.** **Do you notice any difference in the way that speech sounds since receiving your implant?**
(circle as appropriate)

**YES** **NO**

**17.** **If yes, what do you find different about speech since receiving your implant?**
**(**tick **one** box from each column**)**

(i) The words sound: (Tick **one** box as appropriate)
Clearer to me now ☐ Less clear to me now ☐ Just the same ☐

(ii) The speaker's voice sounds: (Tick **one** box as appropriate)
Clearer to me now ☐ Less clear to me now ☐ Just the same ☐

(iii) The meaning of the words are: (Tick **one** box as appropriate)
Clearer to me now ☐ Less clear to me now ☐ Just the same ☐

**18.** **Which of the following best describes the sound of men's and women's voices through your implant?** (Tick **one** box as appropriate)

1 = Men's voices sound much better ☐
2 = Men's voices sound better ☐
3 = Men's voices sound a little better ☐
4 = Men's and women's voices sound about the same ☐
5 = Women's voices sound a little better ☐
6 = Women's voices sound better ☐
7 = Women's voices sound much better ☐

**19.** **Which of the following best describes the sound of men's and children's voices through your implant?** (Tick **one** box as appropriate)

1 = Men's voices sound much better ☐
2 = Men's voices sound better ☐
3 = Men's voices sound a little better ☐
4 = Men's and children's voices sound about the same ☐
5 = Children's voices sound a little better ☐
6 = Children's voices sound better ☐
7 = Children's voices sound much better ☐

**20.** **Which of the following best describes the sound of women's and children's voices through your implant?** (Tick **one** box as appropriate)

1 = Women's voices sound much better ☐
2 = Women's voices sound better ☐
3 = Women's voices sound a little better ☐
4 = Women's and children's voices sound about the same ☐
5 = Children's voices sound a little better ☐
6 = Children's voices sound better ☐
7 = Children's voices sound much better ☐

21. **Since receiving your implant, do you find it harder to understand speech when there is background noise (noisy conditions)?** (circle as appropriate)

**YES** **NO**

22. **Are there any situations where you seem to have a lot of trouble understanding speech? If there are please describe them:**

____________________________________________________________

____________________________________________________________

____________________________________________________________

23. **If you are talking on the telephone, how much can you understand of what the other person is saying?** (Tick <u>one</u> box as appropriate)

1 = None ☐
2 = Very Little ☐
3 = A‹ little ☐
4 = About half ☐
5 = A lot ☐
6 = Almost all ☐
7 = Everything ☐

24. **How often did you <u>choose</u> to listen to music before you became deaf?** (Tick <u>one</u> box as appropriate)

1 = Never ☐
2 = Very rarely (once a month) ☐
3 = Rarely (once a week) ☐
4 = Sometimes (more than once a week) ☐
5 = Quite frequently (less than once a day) ☐
6 = Frequently (once a day) ☐
7 = Very frequently (more than once a day) ☐

25. **What types of music did you enjoy listening to before becoming deaf?**
(Tick as appropriate)

| | | | | | |
|---|---|---|---|---|---|
| Folk | ☐ | Rock | ☐ | Reggae | ☐ |
| Country | ☐ | Opera | ☐ | Rap/Hip Hop | ☐ |
| Classical | ☐ | Pop (since 1960) | ☐ | Pop (before 1960) | ☐ |
| Jazz | ☐ | Easy Listening | ☐ | World | ☐ |
| Blues | ☐ | Musicals | ☐ | Solo Instrumental | ☐ |
| Electro | ☐ | Other | ☐ | | |

25(b). **If ‘other’, please tell us about it. Also, feel free to add any other information that may be appropriate:**

____________________________________________________________

____________________________________________________________

____________________________________________________________

26. **How often do you <u>choose</u> to listen to music <u>since</u> receiving your implant?** (Tick <u>one</u> box as appropriate)

1 = Never ☐
2 = Very rarely (once a month) ☐
3 = Rarely (less than once a week) ☐
4 = Sometimes (more than once a week) ☐
5 = Quite frequently (once a week) ☐
6 = Frequently (once a day) ☐
7 = Very frequently (more than once a day) ☐

**27.** **What types of music do you enjoy listening to <u>since</u> receiving your implant?** (Tick as appropriate)

| | | | | | |
|---|---|---|---|---|---|
| Folk | ☐ | Rock | ☐ | Reggae | ☐ |
| Country | ☐ | Opera | ☐ | Rap/Hip Hop | ☐ |
| Classical | ☐ | Pop (since 1960) | ☐ | Pop (before 1960) | ☐ |
| Jazz | ☐ | Easy Listening | ☐ | World | ☐ |
| Blues | ☐ | Musicals | ☐ | Solo Instrumental | ☐ |
| Electro | ☐ | Other | ☐ | | |

**27(b).** **If 'other', please tell us about it. Also, feel free to add any other information that may be appropriate:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**27(c).** **If your music listening habits have changed since being implanted, would you say that this is due to the fact that you now use a cochlear implant?** (circle as appropriate)

**YES** **NO**

**28.** **Do you notice any difference in the way that music sounds since receiving your implant?** (circle as appropriate)

**YES** **NO**

**29.** **If yes, what do you find different about the music since receiving your implant? (**tick **<u>one</u>** box from each column**)**

(i) The tune/melody sounds: (Tick **<u>one</u>** box as appropriate)
Clearer to me now ☐ Less clear to me now ☐ Just the same ☐

(ii) The instruments sound: (Tick **<u>one</u>** box as appropriate)
Clearer to me now ☐ Less clear to me now ☐ Just the same ☐

(iii) The beat/rhythms sound: (Tick **<u>one</u>** box as appropriate)
Clearer to me now ☐ Less clear to me now ☐ Just the same ☐

**29 (b).** **Please give details about your answers:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**30.** **Are there some instruments that sound particularly <u>good</u> through your implant? If so, why? Please give details:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**31.** **Are there some instruments that sound particularly <u>bad</u> through your implant? If so, why? Please give details:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**32.** **Which is more important to you; music or speech?** (Tick __one__ box as appropriate)

1 = Music much less important ☐
2 = Music less important ☐
3 = Music a bit less important ☐
4 = Both equally important ☐
5 = Music a bit more important ☐
6 = Music more important ☐
7 = Music much more important ☐

**33.** **Did you play a musical instrument before becoming deaf/receiving your implant?** (circle as appropriate):

**YES** **NO**

**34.** **If 'yes', what instrument(s) did you play?** ______________________________

______________________________________________

______________________________________________

**35.** **Did you have music lessons before becoming deaf/receiving your implant?** (circle as appropriate)

**YES** **NO** **NOT APPLICABLE**

**36.** **If 'yes', please give details:** ______________________________

______________________________________________

______________________________________________

**37.** **Did you play this instrument in a group or an ensemble etc.?** (circle as appropriate)

**YES** **NO** **NOT APPLICABLE**

**38.** **If 'yes', please give details:** ______________________________

______________________________________________

______________________________________________

**39.** **Do you play this (or any instrument) since receiving your implant?** (Circle as appropriate)

**YES** **NO**

**40.** **If 'yes', please give details:** ______________________________

______________________________________________

______________________________________________

**41.** **If you had music lessons on your instrument prior to receiving your implant, have you continued with these lessons?** (circle as appropriate)

**YES** **NO** **NOT APPLICABLE**

**42.** **Please give details if appropriate:** ______________________________

______________________________________________

______________________________________________

**43.** **If you still play an instrument, since receiving your implant, do you play it in a group or ensemble etc.?** (circle as appropriate)

**YES** **NO** **NOT APPLICABLE**

**44.** **Please give details if appropriate:** ______________________________

______________________________

______________________________

**45.** **Did you enjoy singing more before or since receiving your implant?** (Tick <u>one</u> box as appropriate)

1 = Much better before ☐
2 = Better before ☐
3 = Mostly better before ☐
4 = No difference ☐
5 = Mostly better now ☐
6 = Better now ☐
7 = Much better now ☐

**46.** **From your perspective, has the sound of your singing voice changed since receiving your implant? Please give details:**

______________________________

______________________________

**47.** **We would really appreciate any other information you have about music through your cochlear implant. Please use the space below to tell us anything that you feel relevant including your thoughts and feeling about music since receiving your implant:**
(Please continue on a separate sheet of paper if necessary.)

______________________________

______________________________

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**Please return this questionnaire, along with the Future Research form if you wish to be involved in the future research outlined in your information sheet, to the following address:**

**Zack A. Moir (PhD Student)**
**University of Edinburgh - Music**
**Alison House**
**12 Nicolson Square**
**Edinburgh**
**EH8 9DF**

**Please feel free to contact me at this address or at zack.moir@ed.ac.uk if you have any questions or suggestions regarding this study.**

**Thank you very much for taking the time to complete this questionnaire.**

# Appendix C

# Musical Experiences Questionnaire

# Free Response Answers

**Congenitally Deaf Group:**

‘Understanding Lyrics is very hard. Music played at very high volumes i.e. in a pub or nightclubs can be distorted.’

‘Although I can hear the instruments and the beats, I cannot hear the person singing and it comes out as noise. I would love to be able to hear the singing as I am loving music after the cochlear implant. With rap music I can almost make out most words if I have it written down and follow the words whilst the music is playing.’

‘Even though I am a big fan of music I don’t think I appreciate the sound of music as much as I would have if I were hearing or a HA [hearing aid] user with a good level of hearing. Ballads or any songs of that sort seem to suit me best for some reason, or men with high voices such as Mika. If I could improve anything with my CI I would take away the messy sounds in orchestras and rock music as mentioned above. Sometimes rock music will sound like one big buzz. As for orchestras, the lower instruments like the cello or bass distort the sound to make it sound like one big buzz.’

‘I love music, there are very few things I appreciate more in terms of sound.’ *‘I think that the sounds are clearer but the words are still hard to pick up when there are a lot of instruments playing at the same time.’*

*‘Understanding Lyrics is very hard. Music played at very high volumes i.e. in a pub or nightclubs can be distorted.’*

*‘Although I can hear the instruments and the beats, I cannot hear the person singing and it comes out as noise. I would love to be able to hear the singing as I am loving music after the cochlear implant. With rap music I can almost make out most words if I have it written down and follow the words whilst the music is playing.’*

*‘Even though I am a big fan of music I don’t think I appreciate the sound of music as much as I would have if I were hearing or a HA [hearing aid] user with a good*

*level of hearing. Ballads or any songs of that sort seem to suit me best for some reason, or men with high voices such as Mika. If I could improve anything with my CI I would take away the messy sounds in orchestras and rock music as mentioned above. Sometimes rock music will sound like one big buzz. As for orchestras, the lower instruments like the cello or bass distort the sound to make it sound like one big buzz.'*

*'I love music, there are very few things I appreciate more in terms of sound.'*

***Pre-Adolescent-Deafened Group:***

*'The melody and higher frequency sounds were getting very difficult to hear prior to getting my implant. These sounds have since returned to their normal volumes.'*

*'All I can say is that I miss hearing music but cannot complain as I hear other sounds that I've never heard in my life like birds chirping, trees rustling, sound of water running, cat purring, dog sighing, babies cooing, and many more so really its amazing and overwhelming for me to be able to hear these things. Maybe later I will be able to hear music as it's still early (only 8 months ago since I got the implant).'*

*'I feel frustrated in a way since receiving my CI because I thought I'd hear music a lot clearer and better than before but when I go to rock gigs or rock clubs I find it impossible to hear a song clearly it just sounds like a racket. Also I find I don't recognise songs when they are being played since I've had the implant but I've actually known the song for a long time and could hear it completely fine with the digital Has [Hearing Aids]. Also, in songs I could hear the singers voice but the guitar bass and drums sound distorted since the implant.'*

*'I cannot pick out individual words in a song unless I have the lyrics in front of me. I enjoy all forms of music and find it much more enjoyable having two implants. In a few of the questions I was unable to answer as I was only 5 and am unable to remember much about being hearing-abled.'*

*'Having a CI has changed my life so much. I have got back my independence and confidence. I hear so much more now and cant believe how much my life has come back and how much I can take part in so many every day things.'*

*'Female singing voices very difficult to hear but when volume level is set very low it is easier to pick up the tune. Sometimes difficult to recognise female singing voice (it can sound male)! When listening to brass ensembles it is hard to pick out different instruments so that it's difficult to recognise even familiar melodies.'*

*'Two of my best pals are big music fans and they could never understand why I didn't listen to music. After my implant operation I realised what I was missing and started listening to older songs I heard prior to my operation so my taste in music has now changed. Personally, my problem is listening to my MP3 player. The lead is heavy and often pulls the sound processor off my ear.'*

*'I love hearing music but I cant make out the words of songs due to the background music.'*

*'I have always enjoyed listening to music (pre and post implant) I have found that if I like the sound of a song, if the words are on the album cover, I will learn the words to the song and whenever the song comes on I can sing the words alongside the music as I know the words. If you played a piece of music to me I wont be able to tell you what they are singing because I can never make out the words to the songs and still have this problem after the implant. I recognise certain songs but I will never be able to sing the song as it is playing because unless I have read the words to the song beforehand, I cant make out the words to the song - this problem has never changed for me.'*

*'My implant has been extremely successful in helping me to hear noise and birds, traffic, sirens, and general sound in the world around me. If you consider I could assist you in the future then please let me know.'*

*'I am disappointed to find there is no improvement in my appreciation of music. I*

*visited theatres where there are captioned subtitles to help me hear and I follow slightly better in musicals and pantomimes e.g. Joseph, My Fair Lady or Sleeping Beauty.*

*'Would love to get the whole thing with music it's a happy fun thought.'*

*'I used to listen to Elvis since I was 15 with my old behind the ear hearing aid and it sounded more natural to me all these years but now with the implant it sounds funny and not natural. I don't think I would have went for an implant if I knew I would not be able to hear my favourite singer and others. Music and lyrics were easier to understand with the old hearing aid.'*

*'Since receiving my implant I really enjoy listening to music. The music is clearer and I have a greater appreciation of the different instruments.' 'Being associated in the music industry from Roadie to working in studios, have a fair comprehension of music. I gave up the music side when hearing loss became severe, but since cochlear implant can in a small way appreciate music and I do tend to listen to music programs, but to play again would I feel be a bit difficult as pitch sounds completely different and off key. Playing by ear is out, although basic music theory can help as you can know where the notes required are on a properly tuned keyboard. String instruments are an impossibility, when they sound out of tune as with a cochlear implant you rarely hear any changes in pitch. As I am now into multimedia one of the biggest problems I have is being able to cut and insert music into film and video as the music can become fused and not easy to separate.'*

*'The melody and higher frequency sounds were getting very difficult to hear prior to getting my implant. These sounds have since returned to their normal volumes.'*

*'All I can say is that I miss hearing music but cannot complain as I hear other sounds that I've never heard in my life like birds chirping, trees rustling, sound of water running, cat purring, dog sighing, babies cooing, and many more so really its amazing and overwhelming for me to be able to hear these things. Maybe later I will*

*be able to hear music as it's still early (only 8 months ago since I got the implant).'*

*'I feel frustrated in a way since receiving my CI because I thought I'd hear music a lot clearer and better than before but when I go to rock gigs or rock clubs I find it impossible to hear a song clearly it just sounds like a racket. Also I find I don't recognise songs when they are being played since I've had the implant but I've actually known the song for a long time and could hear it completely fine with the digital Has [Hearing Aids]. Also, in songs I could hear the singers voice but the guitar bass and drums sound distorted since the implant.'*

*'I cannot pick out individual words in a song unless I have the lyrics in front of me. I enjoy all forms of music and find it much more enjoyable having two implants. In a few of the questions I was unable to answer as I was only 5 and am unable to remember much about being hearing-abled.'*

*'Having a CI has changed my life so much. I have got back my independence and confidence. I hear so much more now and cant believe how much my life has come back and how much I can take part in so many every day things.'*

*'Female singing voices very difficult to hear but when volume level is set very low it is easier to pick up the tune. Sometimes difficult to recognise female singing voice (it can sound male)! When listening to brass ensembles it is hard to pick out different instruments so that it's difficult to recognise even familiar melodies.'*

*'Two of my best pals are big music fans and they could never understand why I didn't listen to music. After my implant operation I realised what I was missing and started listening to older songs I heard prior to my operation so my taste in music has now changed. Personally, my problem is listening to my MP3 player. The lead is heavy and often pulls the sound processor off my ear.'*

*'I love hearing music but I cant make out the words of songs due to the background music.'*

*'I have always enjoyed listening to music (pre and post implant) I have found that if*

*I like the sound of a song, if the words are on the album cover, I will learn the words to the song and whenever the song comes on I can sing the words alongside the music as I know the words. If you played a piece of music to me I wont be able to tell you what they are singing because I can never make out the words to the songs and still have this problem after the implant. I recognise certain songs but I will never be able to sing the song as it is playing because unless I have read the words to the song beforehand, I cant make out the words to the song - this problem has never changed for me.'*

*'My implant has been extremely successful in helping me to hear noise and birds, traffic, sirens, and general sound in the world around me. If you consider I could assist you in the future then please let me know.'*

*'I am disappointed to find there is no improvement in my appreciation of music. I visited theatres where there are captioned subtitles to help me hear and I follow slightly better in musicals and pantomimes e.g. Joseph, My Fair Lady or Sleeping Beauty.*

*'Would love to get the whole thing with music it's a happy fun thought.'*

*'I used to listen to Elvis since I was 15 with my old behind the ear hearing aid and it sounded more natural to me all these years but now with the implant it sounds funny and not natural. I don't think I would have went for an implant if I knew I would not be able to hear my favourite singer and others. Music and lyrics were easier to understand with the old hearing aid.'*

*'Since receiving my implant I really enjoy listening to music. The music is clearer and I have a greater appreciation of the different instruments.'*

***Late-Deafened Group:***

*'I am gradually building up tolerance to having music on - at first, it was really distracting and I got wound up. I can have it on a lot now. Hearing music again has*

*been very emotional, tears well up and I feel great joy - it really is thrilling. I have realised for a long time that I am 'outside' or 'uninvolved' in occasions like baptisms, carol concerts, nativity plays (where i should be moved) because of lack of sound. Now I enjoy them emotionally. So far, I cannot make anything of modern pop music and don't like the constant jangle that is the background to speech on pop programs. I feel I have at least a two-decade gap in my musical knowledge and I don't know what to do about it. I think I have also forgotten a lot of music through disuse.'*

*'I do not enjoy music any more, however, I do hear beats more than before. I do think that live music is better than music from TV and radio.'*

*'I sang in a choir, I'm a soprano, I've sung with Cleo Lane at the Stables in her workshop. I've snag Handle's Messiah at the Royal Albert Hall, I enjoy hymns and have been known to sing to the tune in my head when others sing them!'*

*'Listening to music that is further away seems to distort. I have a cable to attach to an mp3 direct to my processor and the quality through that is good.'*

*'I miss hearing it [music] properly.'*

*'I still really enjoy music. Although modern music is a bit difficult to get to grips with, at least there appears to be a definite rhythm. I used to be a disc jockey.'*

*'The speech processor is an excellent tool and well supported by qualified staff (which is 1/3 of the process and the other 2/3 has to be done by the individual). I know that speech and music are in two bandwidths but one day there is no reason why the full value of music software can overcome my hearing problems.'*

*'Music sounds very high pitched and can be very difficult to put up with for long.'*

*'I miss music a great deal. I was always playing some kind of music and I liked to sing around the house to music but my voice sounds terrible now. My hearing is very muffled and people sound as if they have laryngitis, as does my own voice. I find it hard to distinguish voices apart from my own family. I had 3 children at home*

*so I listened to varied voices. Sometimes the silence is better than the sound. My one wish would be for to music to sound better. As a nurse i always say i am a really good listener and rely also on lip-reading.'*

*'As stated above, if I cant recognise a tune I cant follow it. Sometimes it can take a minute or two before I can pinpoint a part I recognise. If it's music I'm not familiar with I can't make it out. I can't make sense of any new music, especially current music. I can get a beat/rhythm but no tune. A lot of the time, music is just a noise. I also have bad tinnitus in both ears, which does not help when trying to listen to music. The implant has not been the cause of this. I still have no hearing in the left ear and only the implant in the right so music balance is not good! '*

*'I enjoy listening to music at the cinema – 'Walk the Line', 'Hairspray' and 'Love Actually'! I like to see the singers singing and enjoy dancing at ceilidhs. Linda Lee Lewis (Jerry's sister) sang and played the piano at a local hotel. My husband and I were up for every dance - fantactic night. I don't like clapping to music! I got an MP3 player last week and can now hear ABBA hits.'*

*'I don't listen to music as I cant recognise words or tunes.'*

*'I used to really enjoy listening to music but since the implant I don't really hear new songs so find it hard to listen to new stuff.'*

*'I have continued to enjoy music although less frequently after being implanted. I do, however, rely on memory for a lot of the tunes and I sometimes have difficulty following the proper key - particularly with church music.'*

*'Regardless of the instruments I am unable to recognise tunes.'*

*'For example, when X-Factor was on, I would always ask my wife if the act was any good as my perception of tone and tune are very poor and it's impossible to pick words out of songs. (I have full admiration for Evlynn Glennie.)'*

*'I love listening to music but I'm restricted now as it does not sound how I remember it - that is my main problem. I do persevere, as I want it to improve, so*

*when I find something I like I tend to stick with that in the hope that it becomes "normal" for me. I also liked going to the theatre but find that difficult as the noise is now overwhelming and you cant hear the voice over the music.'*

*'I really miss music and don't socialise the same way - I miss singing in church and dancing etc. I know I am a pensioner, that's why I have all the time I have and I should be tee-dancing and line-dancing and going to the theater and cinema and musicals and ballet but you miss out on so much if you cant hear music. I don't know if this will make sense, if the song/tune is something I know from before I lost my hearing and if someone tells me the name and sings a little bit of it for me I can kind of 'tune into it'.'*

*'I seem to understand music better when watching it on the TV rather than hearing from a hi-fi, I don't know yet why this is. I do like music although it gets frustrating because it isn't clear enough to enjoy. The voices aren't clear although the actual music is when I listen to songs that I know, before my implant.'*

*'I was very surprised initially not to be able to hear music as anything other than noise. I did persevere on the assumption that the brain could be 'tricked' into hearing known tunes but without success. I heard (so to speak) that children who have implants at a young age enjoy music, as they have no idea of the actual sound - I wonder if because I was musical that this is my problem? I know and remember what it should sound like.'*

*'Music is one of the most difficult sounds to appreciate through the implant as sometimes it is played too loud and hides vocals. The implant does not react the same way that normal hearing does and it cannot tell the brain to differentiate the noises.'*

*'I used to enjoy listening to the three tenors, hopefully in time, I will be able to hear them again. Also, I love bagpipe music!'*

*'I was always a lover of music before the implant but latterly I could not hear any at*

*all and now I can and it's an important part of my life.'*

*'When I go to musicals at the theatre I'm delighted because I can make out the lyrics of my favourite songs in the musical. Just before my implant I found it very hard to make out music at all.' 'The only disappointment I had was not hearing/understanding music. I still cannot music and I hear noise. Funnily enough, if an old film is on television e.g. Breakfast at Tiffany's. I can hear and understand the theme song 'Moon River' as I remember it from when I could hear many years ago. But someone has to tell me when it is played, as I would not recognise it otherwise.'*

*'I am gradually building up tolerance to having music on - at first, it was really distracting and I got wound up. I can have it on a lot now. Hearing music again has been very emotional, tears well up and I feel great joy - it really is thrilling. I have realised for a long time that I am 'outside' or 'uninvolved' in occasions like baptisms, carol concerts, nativity plays (where i should be moved) because of lack of sound. Now I enjoy them emotionally. So far, I cannot make anything of modern pop music and don't like the constant jangle that is the background to speech on pop programs. I feel I have at least a two-decade gap in my musical knowledge and I don't know what to do about it. I think I have also forgotten a lot of music through disuse.'*

*'I do not enjoy music any more, however, I do hear beats more than before. I do think that live music is better than music from TV and radio.'*

*'I sang in a choir, I'm a soprano, I've sung with Cleo Lane at the Stables in her workshop. I've snag Handle's Messiah at the Royal Albert Hall, I enjoy hymns and have been known to sing to the tune in my head when others sing them!'*

*'Listening to music that is further away seems to distort. I have a cable to attach to an mp3 direct to my processor and the quality through that is good.'*

*'I miss hearing it [music] properly.'*

*'I still really enjoy music. Although modern music is a bit difficult to get to grips with, at least there appears to be a definite rhythm. I used to be a disc jockey.'*

*'The speech processor is an excellent tool and well supported by qualified staff (which is 1/3 of the process and the other 2/3 has to be done by the individual). I know that speech and music are in two bandwidths but one day there is no reason why the full value of music software can overcome my hearing problems.'*

*'Music sounds very high pitched and can be very difficult to put up with for long.'*

*'I miss music a great deal. I was always playing some kind of music and I liked to sing around the house to music but my voice sounds terrible now. My hearing is very muffled and people sound as if they have laryngitis, as does my own voice. I find it hard to distinguish voices apart from my own family. I had 3 children at home so I listened to varied voices. Sometimes the silence is better than the sound. My one wish would be for to music to sound better. As a nurse i always say i am a really good listener and rely also on lip-reading.'*

*'As stated above, if I cant recognise a tune I cant follow it. Sometimes it can take a minute or two before I can pinpoint a part I recognise. If it's music I'm not familiar with I can't make it out. I can't make sense of any new music, especially current music. I can get a beat/rhythm but no tune. A lot of the time, music is just a noise. I also have bad tinnitus in both ears, which does not help when trying to listen to music. The implant has not been the cause of this. I still have no hearing in the left ear and only the implant in the right so music balance is not good! '*

*'I enjoy listening to music at the cinema – 'Walk the Line', 'Hairspray' and 'Love Actually'! I like to see the singers singing and enjoy dancing at ceilidhs. Linda Lee Lewis (Jerry's sister) sang and played the piano at a local hotel. My husband and I were up for every dance - fantactic night. I don't like clapping to music! I got an MP3 player last week and can now hear ABBA hits.'*

*'I don't listen to music as I cant recognise words or tunes.'*

*‘I used to really enjoy listening to music but since the implant I don’t really hear new songs so find it hard to listen to new stuff.’*

*‘I have continued to enjoy music although less frequently after being implanted. I do, however, rely on memory for a lot of the tunes and I sometimes have difficulty following the proper key - particularly with church music.’*

*‘Regardless of the instruments I am unable to recognise tunes.’*

*‘For example, when X-Factor was on, I would always ask my wife if the act was any good as my perception of tone and tune are very poor and it’s impossible to pick words out of songs. (I have full admiration for Evlynn Glennie.)’*

*‘I love listening to music but I’m restricted now as it does not sound how I remember it - that is my main problem. I do persevere, as I want it to improve, so when I find something I like I tend to stick with that in the hope that it becomes ”normal” for me. I also liked going to the theatre but find that difficult as the noise is now overwhelming and you cant hear the voice over the music.’*

*‘I really miss music and don’t socialise the same way - I miss singing in church and dancing etc. I know I am a pensioner, that’s why I have all the time I have and I should be tee-dancing and line-dancing and going to the theater and cinema and musicals and ballet but you miss out on so much if you cant hear music. I don’t know if this will make sense, if the song/tune is something I know from before I lost my hearing and if someone tells me the name and sings a little bit of it for me I can kind of ’tune into it’.’*

*‘I seem to understand music better when watching it on the TV rather than hearing from a hi-fi, I don’t know yet why this is. I do like music although it gets frustrating because it isn’t clear enough to enjoy. The voices aren’t clear although the actual music is when I listen to songs that I know, before my implant.’*

*‘I was very surprised initially not to be able to hear music as anything other than noise. I did persevere on the assumption that the brain could be ’tricked’ into*

*hearing known tunes but without success. I heard (so to speak) that children who have implants at a young age enjoy music, as they have no idea of the actual sound - I wonder if because I was musical that this is my problem? I know and remember what it should sound like.'*

*'Music is one of the most difficult sounds to appreciate through the implant as sometimes it is played too loud and hides vocals. The implant does not react the same way that normal hearing does and it cannot tell the brain to differentiate the noises.'*

*'I used to enjoy listening to the three tenors, hopefully in time, I will be able to hear them again. Also, I love bagpipe music!'*

*'I was always a lover of music before the implant but latterly I could not hear any at all and now I can and it's an important part of my life.'*

*'When I go to musicals at the theatre I'm delighted because I can make out the lyrics of my favourite songs in the musical. Just before my implant I found it very hard to make out music at all.'*

# Appendix D

# Mixer Application Screenshots

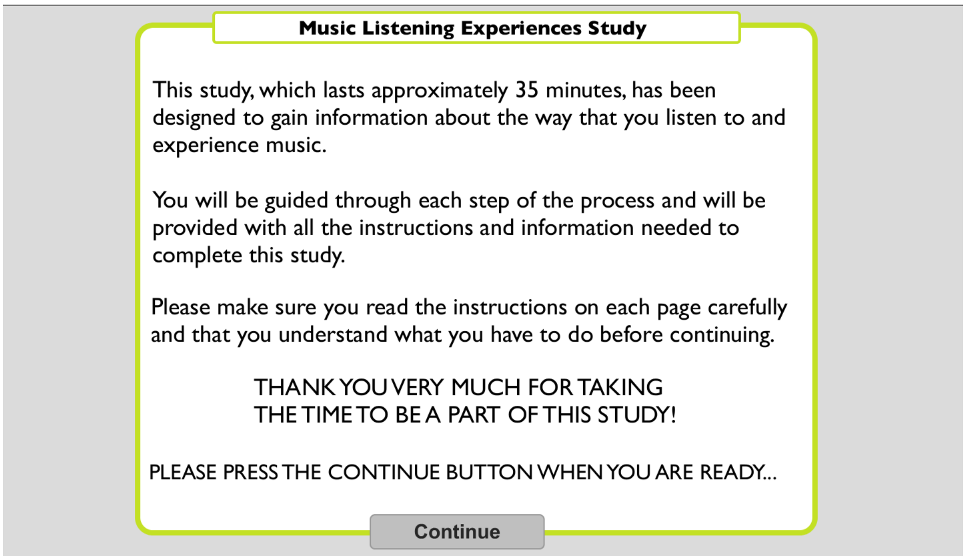



Figure D.1: Mixer Welcome Page

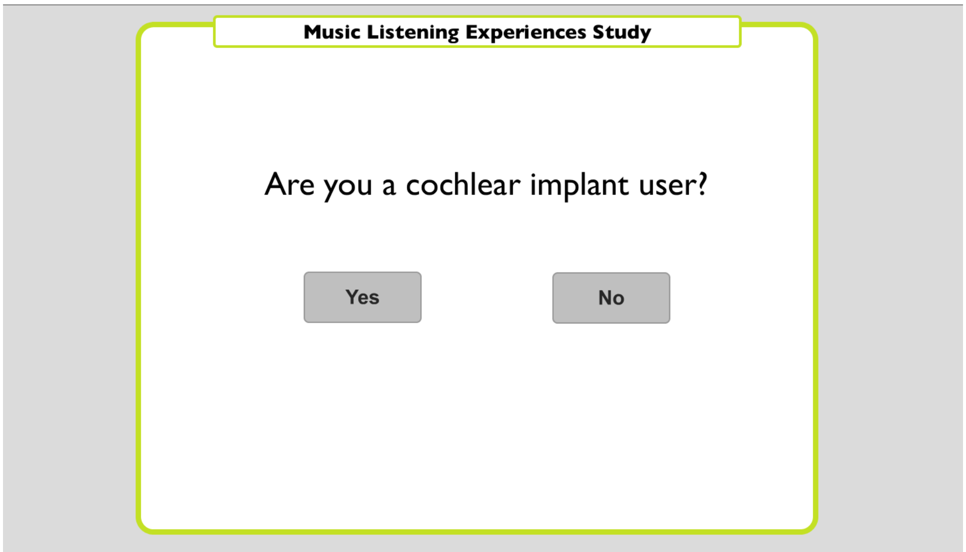



Figure D.2: Mixer User Choice

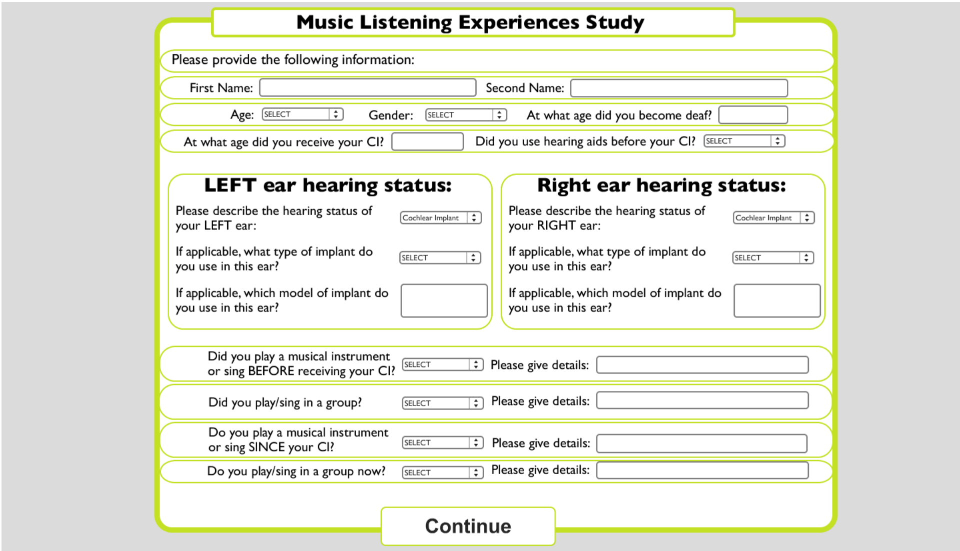



Figure D.3: CIU Participant Details

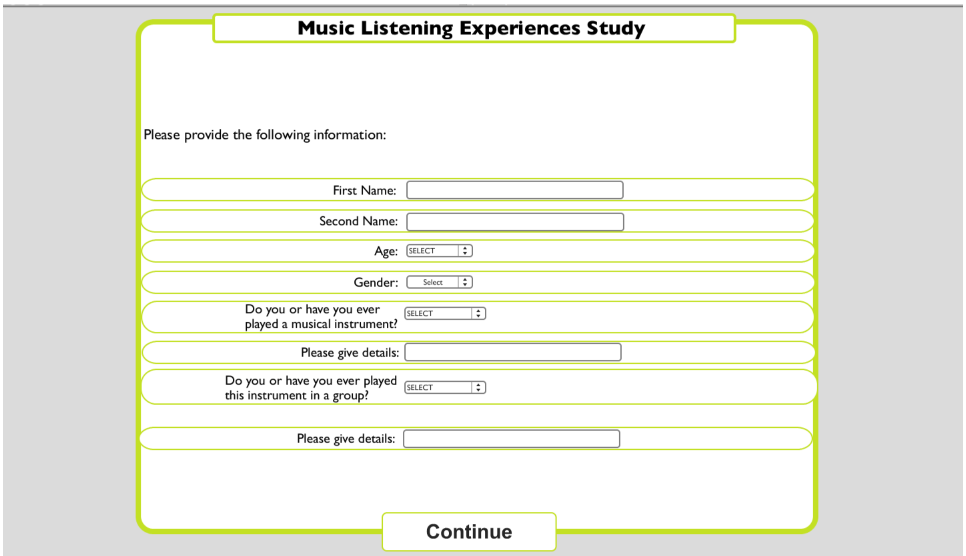



Figure D.4: NH Participant Details

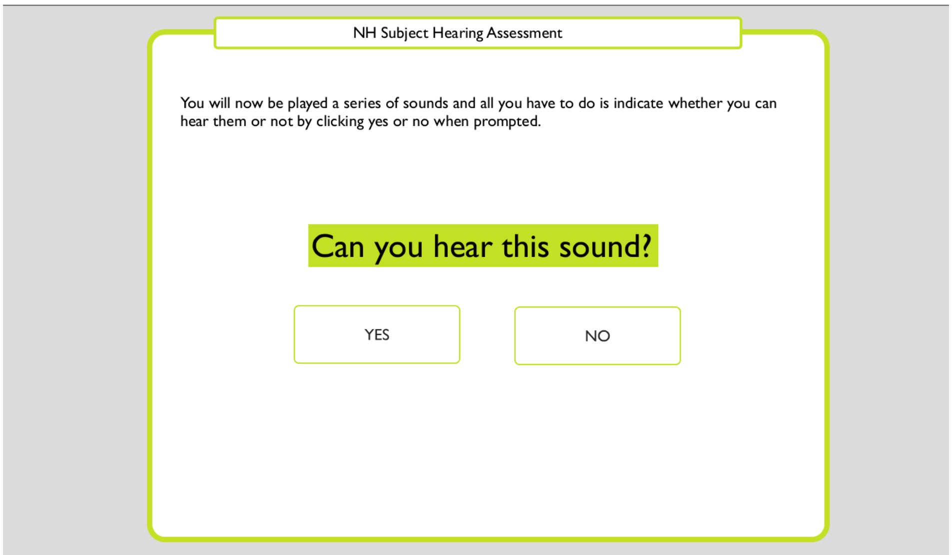



Figure D.5: NH Hearing Test

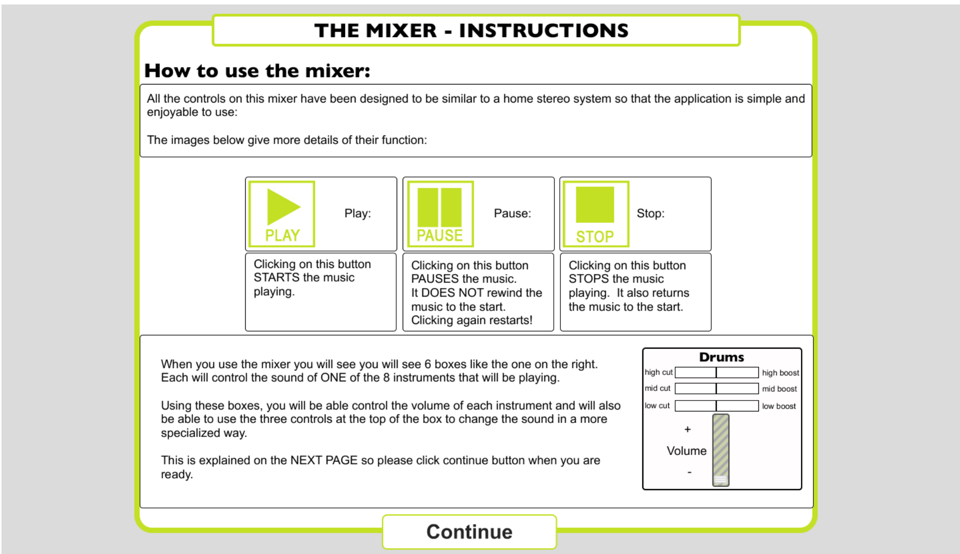



Figure D.6: Mixer Welcome Page

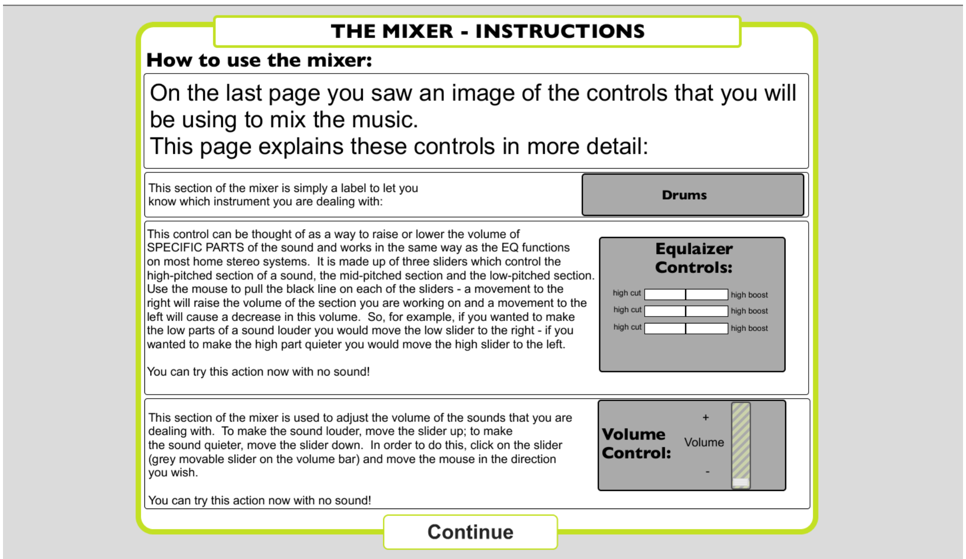



Figure D.7: Mixer Control Instructions Page 1

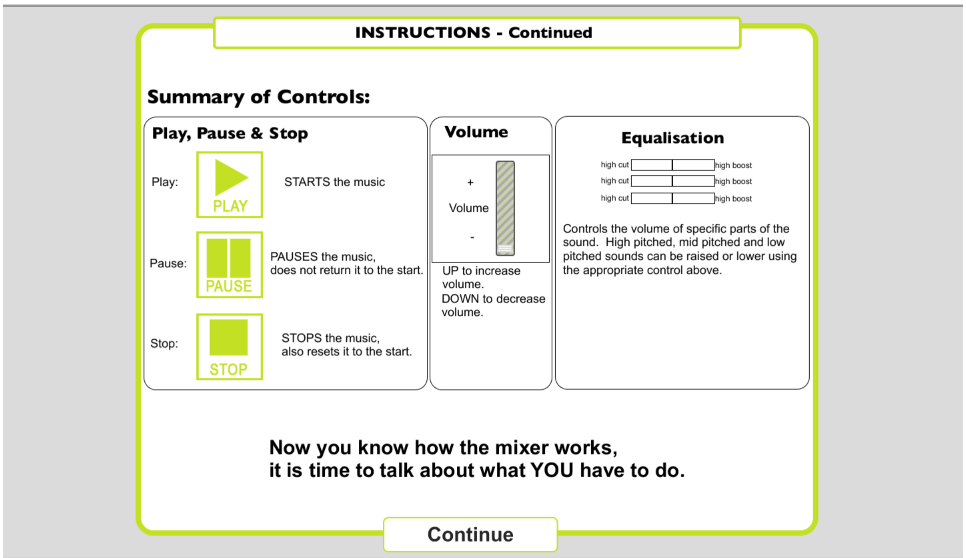



Figure D.8: Mixer Control Instructions Page 2

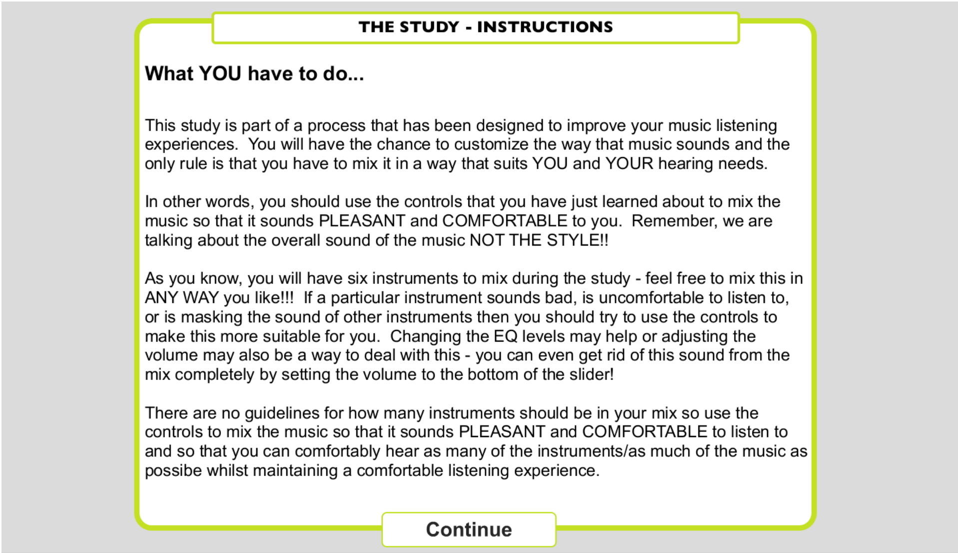



Figure D.9: Mixer Control Instructions Page 3

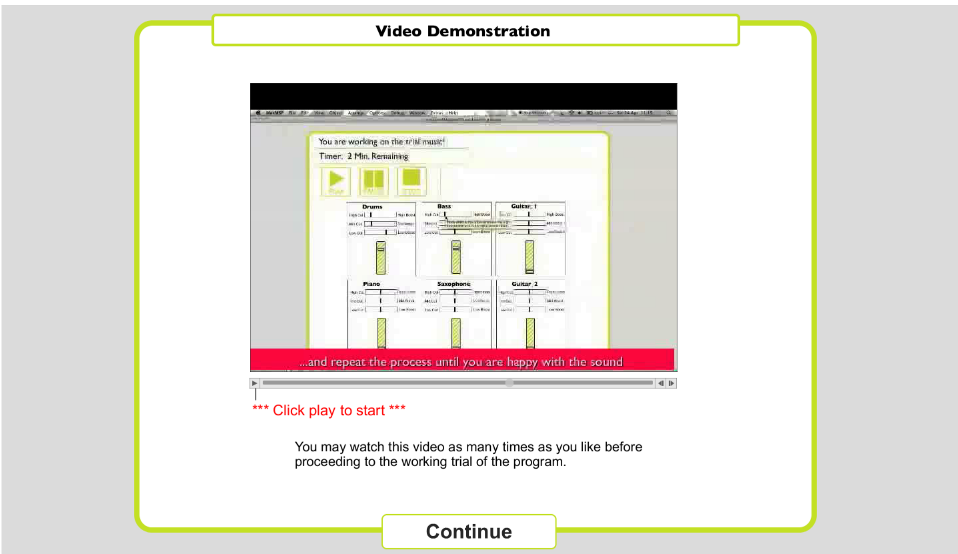



Figure D.10: Instructional Video

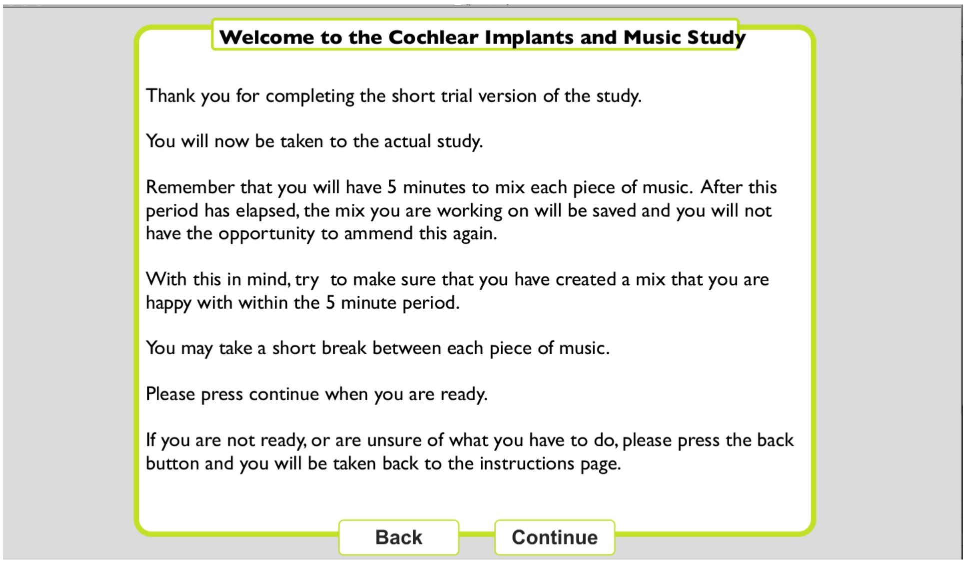



Figure D.11: Mixer Precheck Page

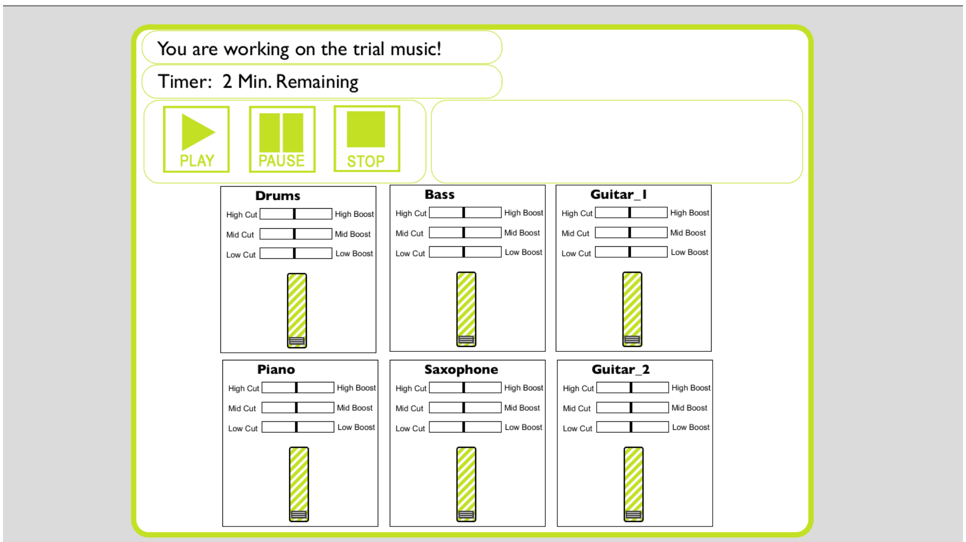



Figure D.12: Mix Interface

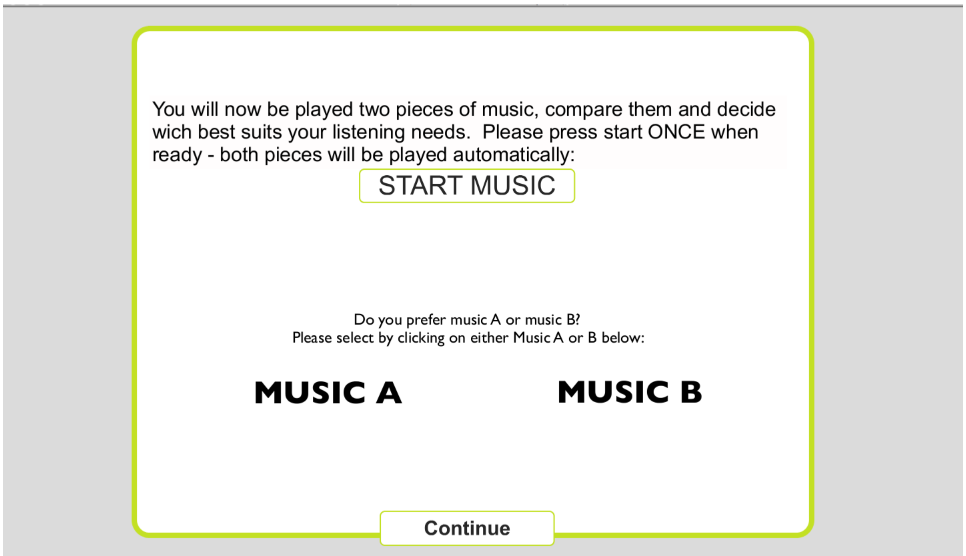



Figure D.13: Mix Comparison

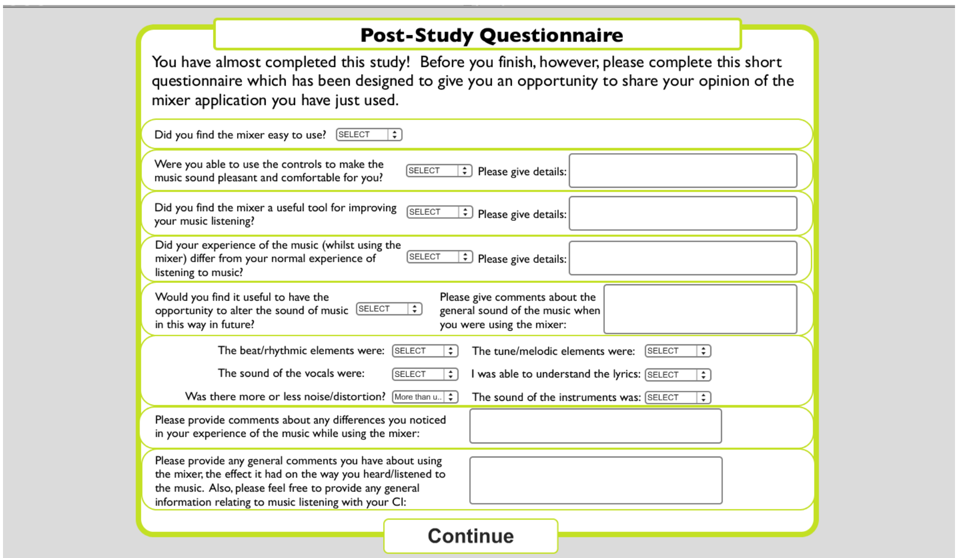



Figure D.14: Mixer Post-Use Questionnaire

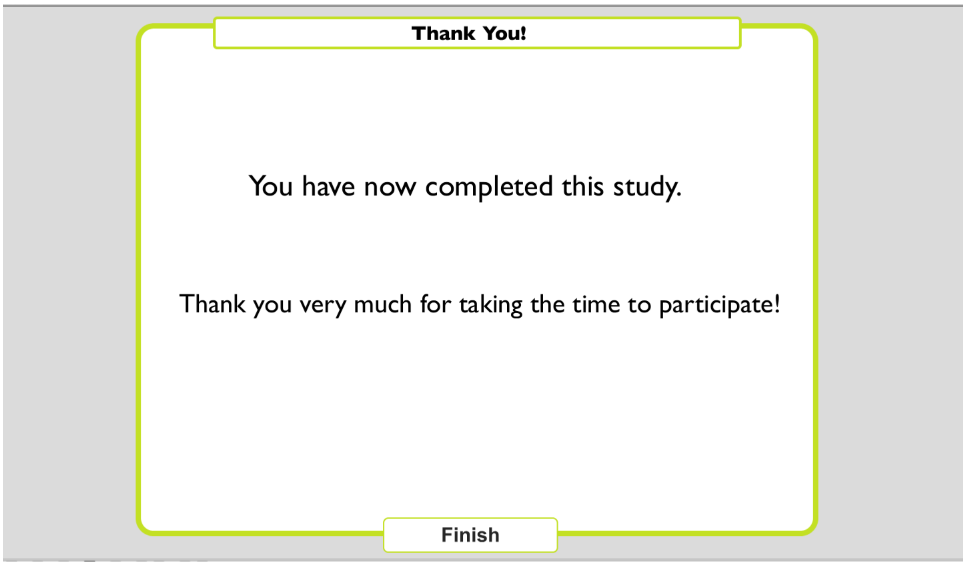



Figure D.15: Mixer End Page

# Appendix E

# Mixer Study - LTAS Individual Results (Grouped)

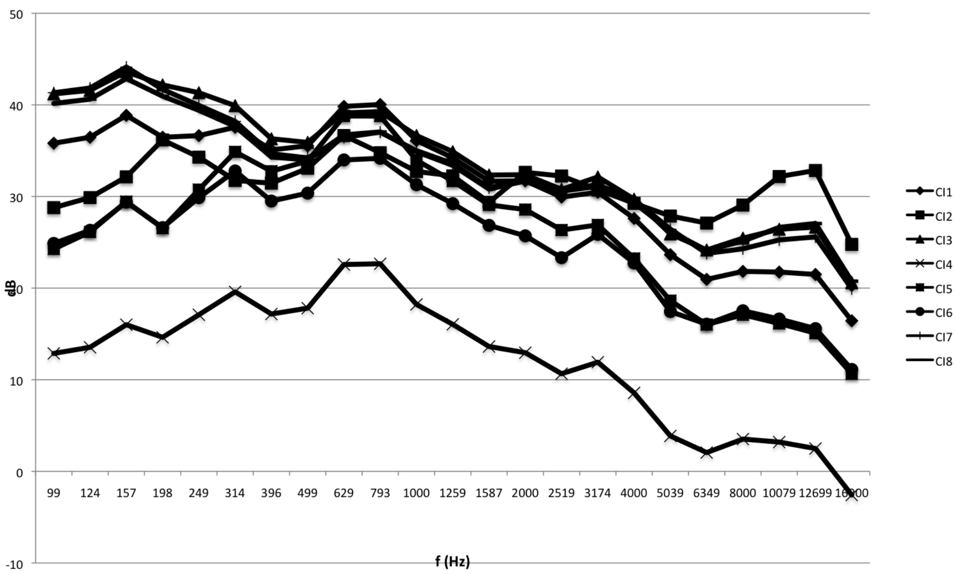



Figure E.1: LTAS of whole mix for each CI participant for piece 1

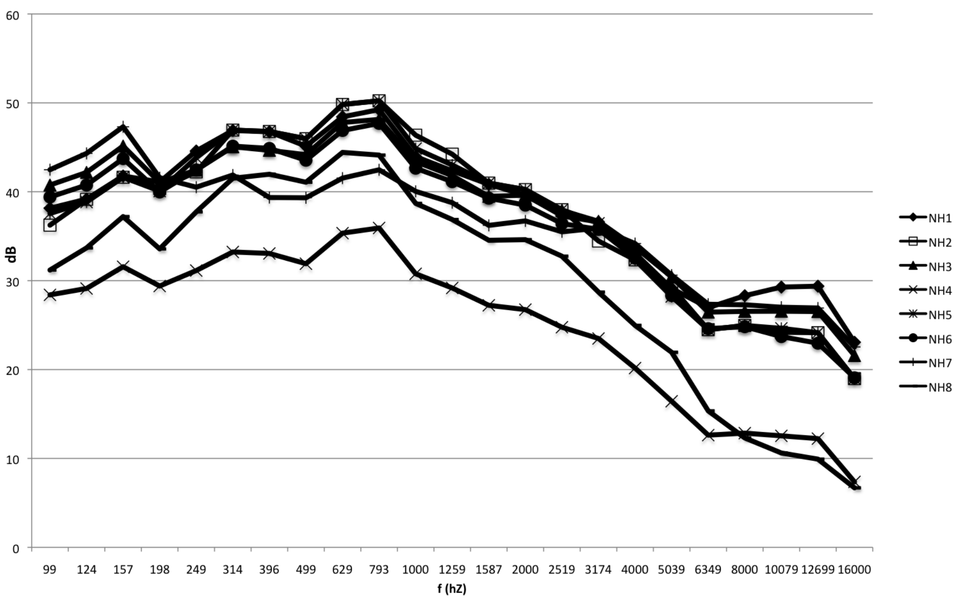



Figure E.2: LTAS of whole mix for each NH participant for piece 1

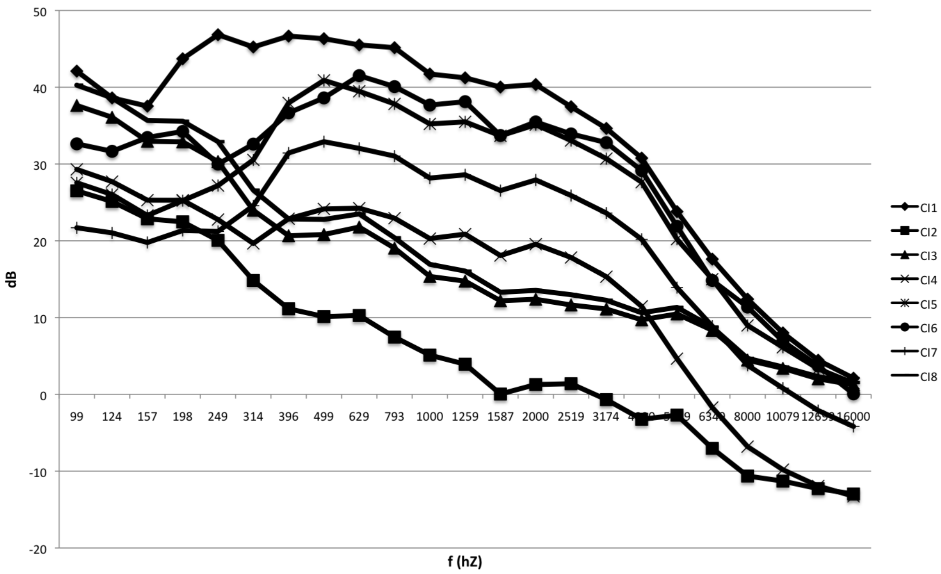



Figure E.3: LTAS of whole mix for each CI participant for piece 2

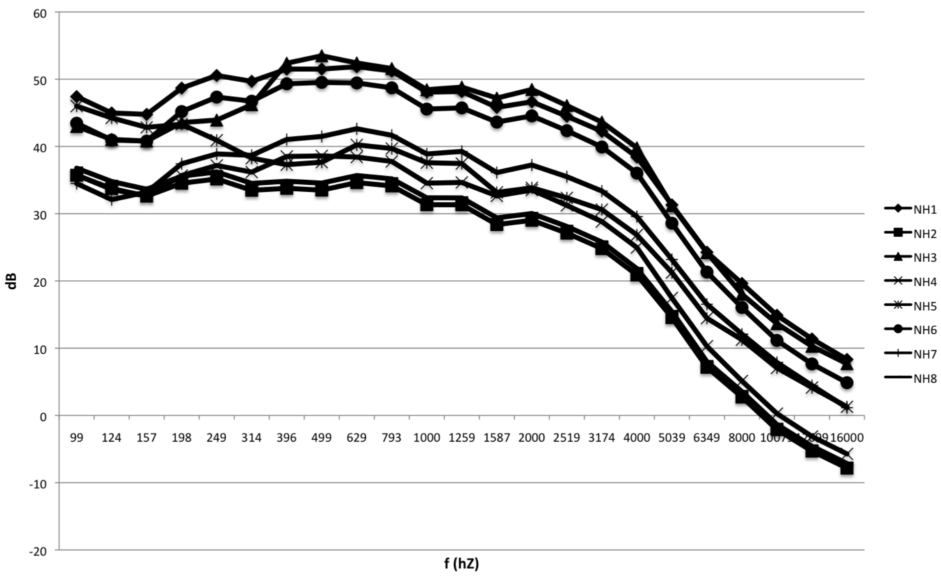



Figure E.4: LTAS of whole mix for each NH participant for piece 2

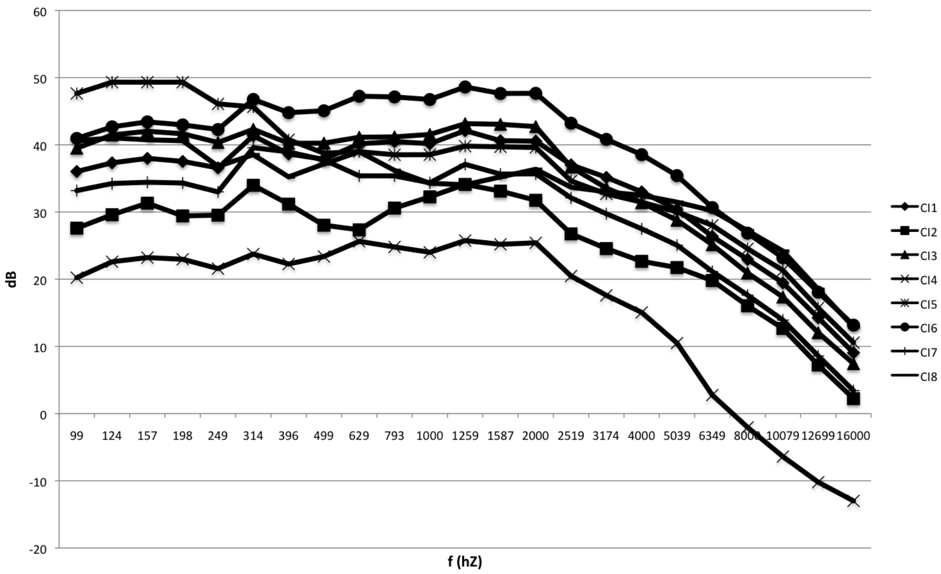



Figure E.5: LTAS of whole mix for each CI participant for piece 3

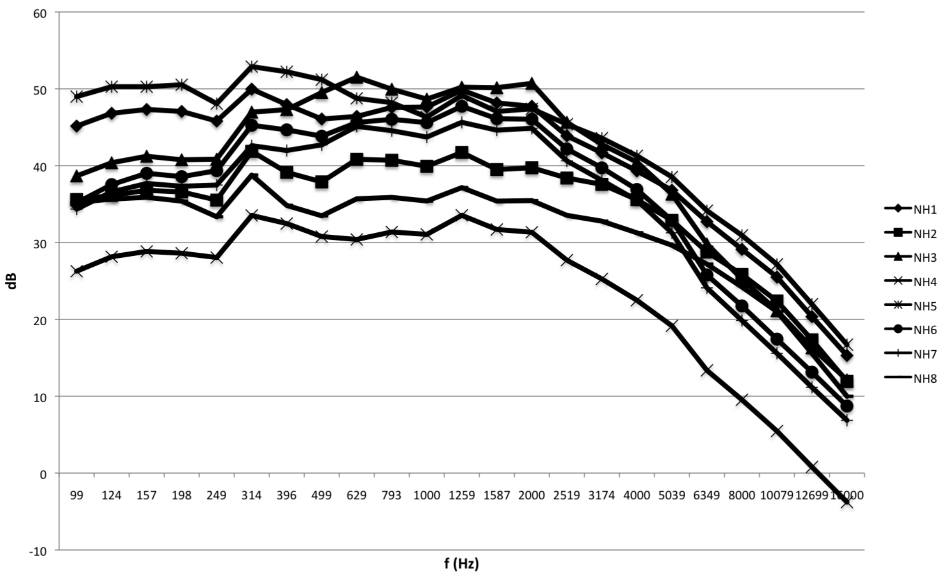



Figure E.6: LTAS of whole mix for each NH participant for piece 3

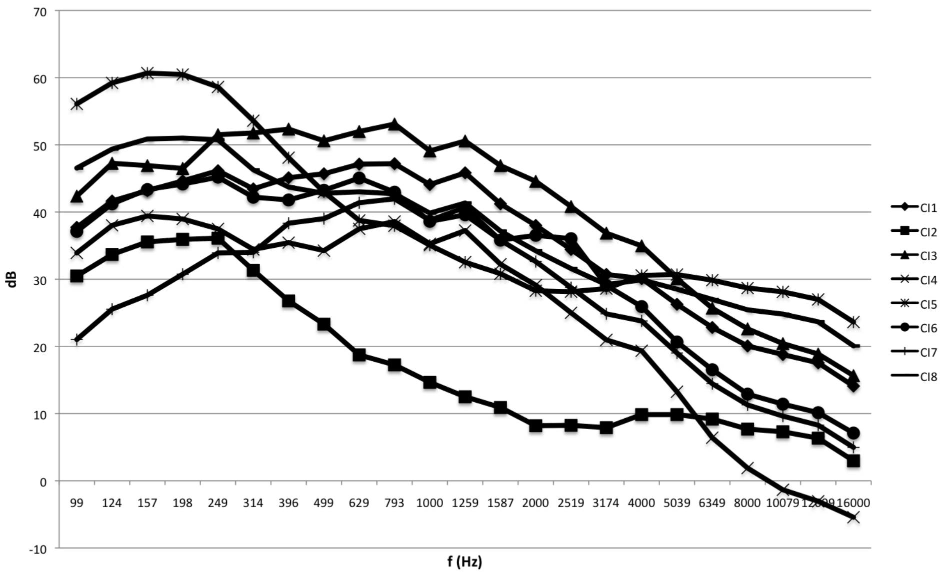



Figure E.7: LTAS of whole mix for each CI participant for piece 4

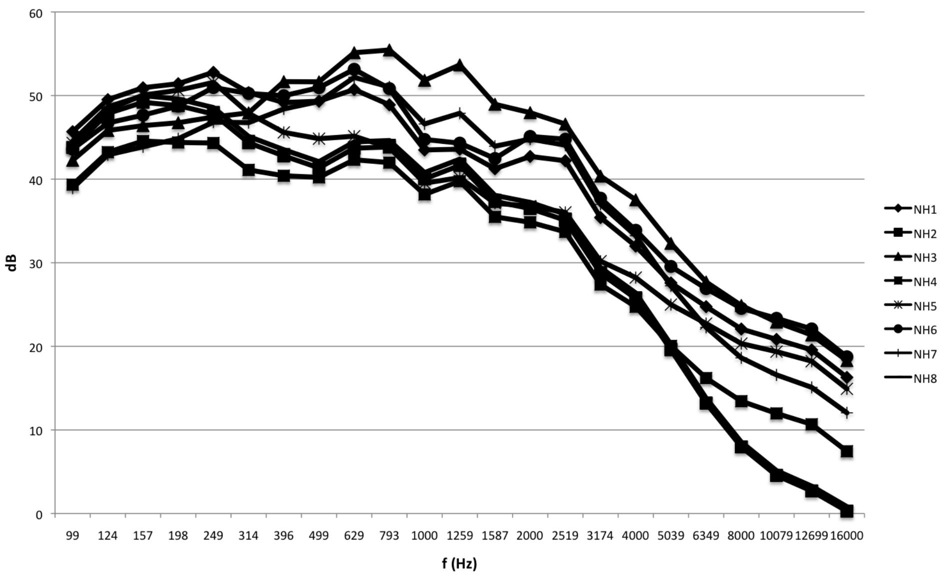



Figure E.8: LTAS of whole mix for each NH participant for piece 4

# Appendix F

# Deacon Audience Feedback

*"Despite the bad ratings I thought it actually sounded better than I expected. I had/have very low expectations for listening to music with a CI although speech is very good."*

*"The music was very good, but the cochlear implant was too loud. I had to switch off."*

*"I found that my enjoyment of listening to a given instrument was maximised when there were little other instruments playing. I found that the saxophone drowned the cello out, or I found it difficult to differentiate between the two, but when they were playing individually it sounded beautiful. I don't know if it's due to personal preference but when instruments increased their pitch I enjoyed it much more. Again, I find it easier and enjoyable to listen to higher voices so I find myself listening to the likes of Mika or James Blunt if not a female voice. All in all it was great!"*

*"This is my first musical night since my cochlear implant and it is such a pleasure and a joy to be re-introduced to live music again. To be able to follow the beat and hear the change in turn and the various instruments was an absolute pleasure. Thank you so much for giving it back to me."*

*"Enjoyed this show this is my first venture listening to music since implant, which I have had just over two months. Look forward to more."*

*"Will appreciate the DVD and look forward to watching it again. The music was awesome. Would also like a CD so I can put it on my iPod."*

*"Would be good idea to employ a cursor on the song lyrics. It is easier to follow the music if one is familiar with the song before deafness."*

*"Very good the story. Good to have something visual. Suggestion (1) Spotlight on singer (2) Point to the words of the song. Enjoyable thank you for the DVD. "Does*

*the DVD have words sheet? Love the instruments and having live music."*

*"I can do with laser pointer to point the words on screen so that I follow and not lose out the words as the singer sings along. Keep up with the good work."*

# Appendix G

# Deacon Scores

## G.1 Prelude

# 1. Prelude

by Zack A. Moir


18
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Militaristic
Dr.
23
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
27
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.


31
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
p
tr
p
35
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
39
Voice
Ten. Sax.
Vc.
LH Mute for percussive sound
(No specific pitch)
A. Gtr.
Bass
Dr.


43
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
p
tr
p
47
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
50
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.

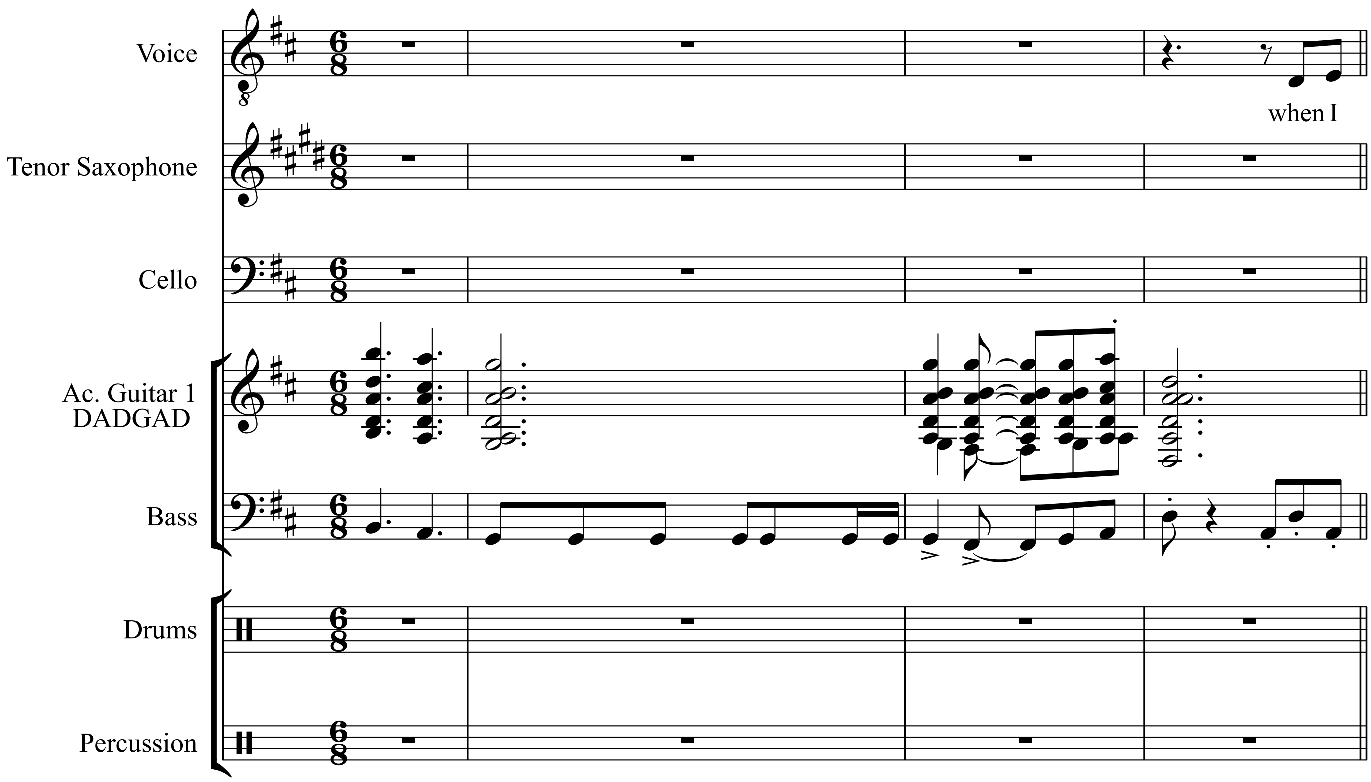

53
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
p
tr
p
56
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
59
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.


62
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
67
tr
f
73
G
cue b
molto rall.

## G.2 Dreams

# 2. Dreams

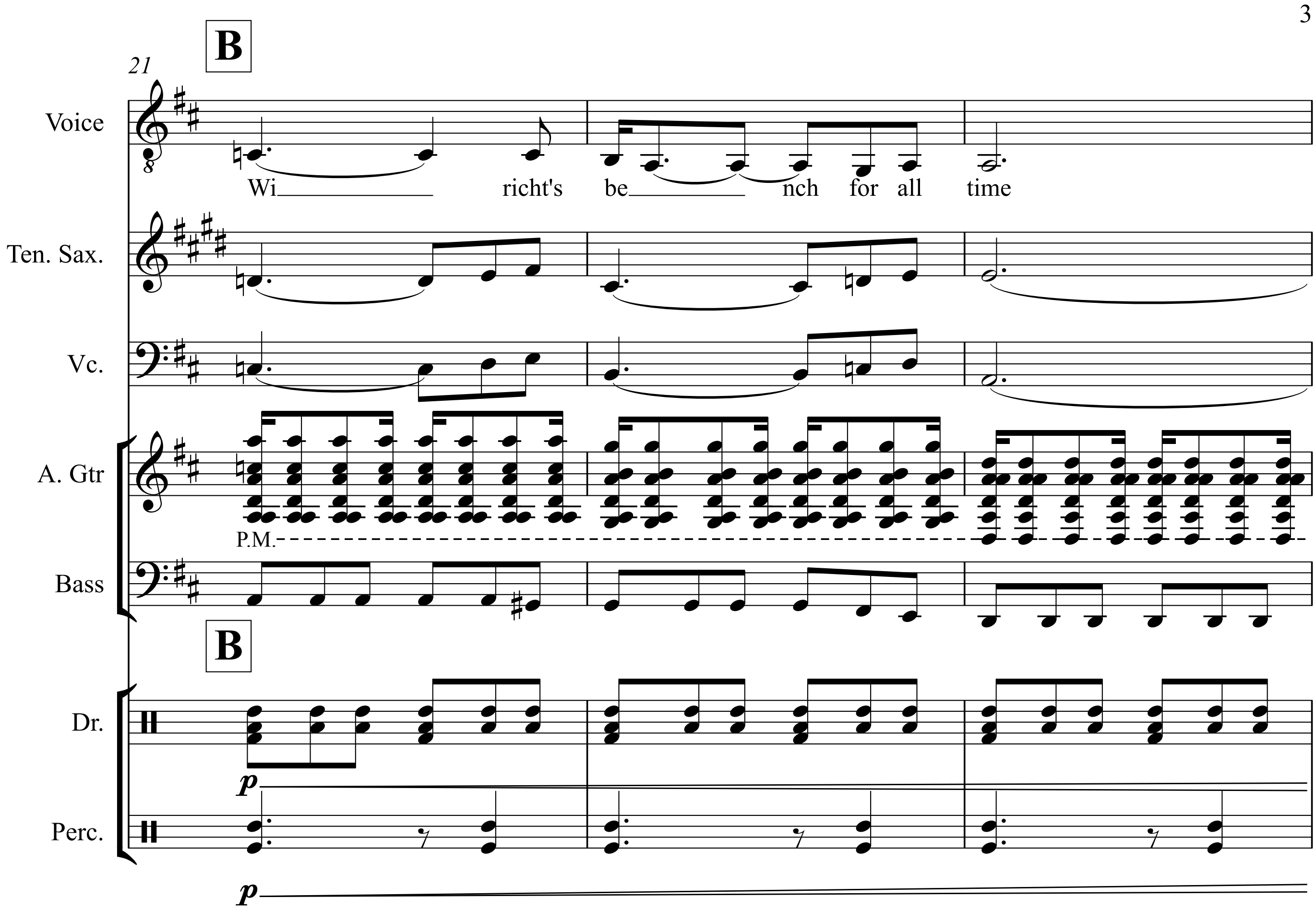
by Zack A. Moir

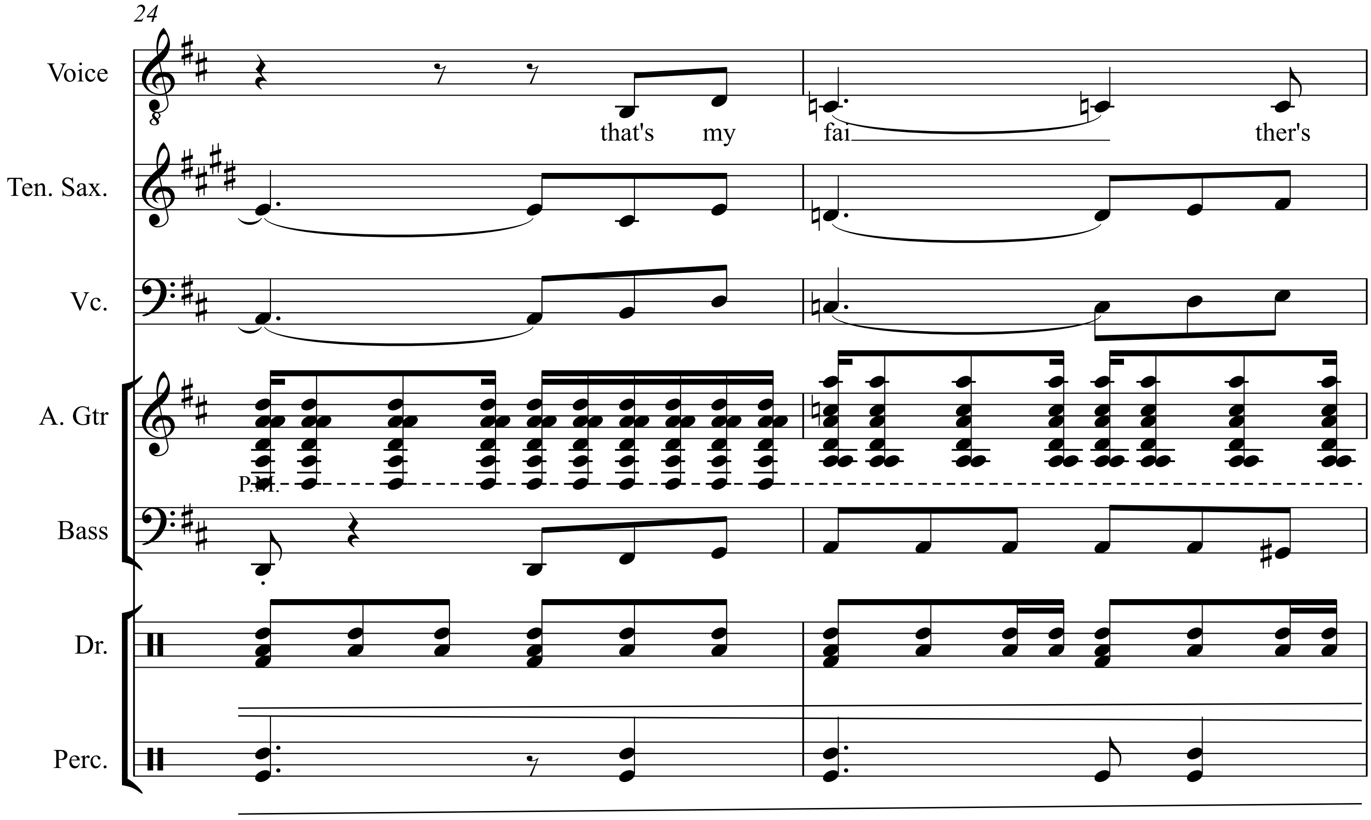




11
Voice
here I could fight with my bro thers for glo ry
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


16
Voice
but my fu tures been set out for me Tied to a
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


B
21
Voice
Wi richt's be nch for all time
Ten. Sax.
Vc.
A. Gtr
P.M.
Bass
B
Dr.
p
Perc.
p


24
Voice
that's my fai ther's
Ten. Sax.
Vc.
A. Gtr
P.M.
Bass
Dr.
Perc.

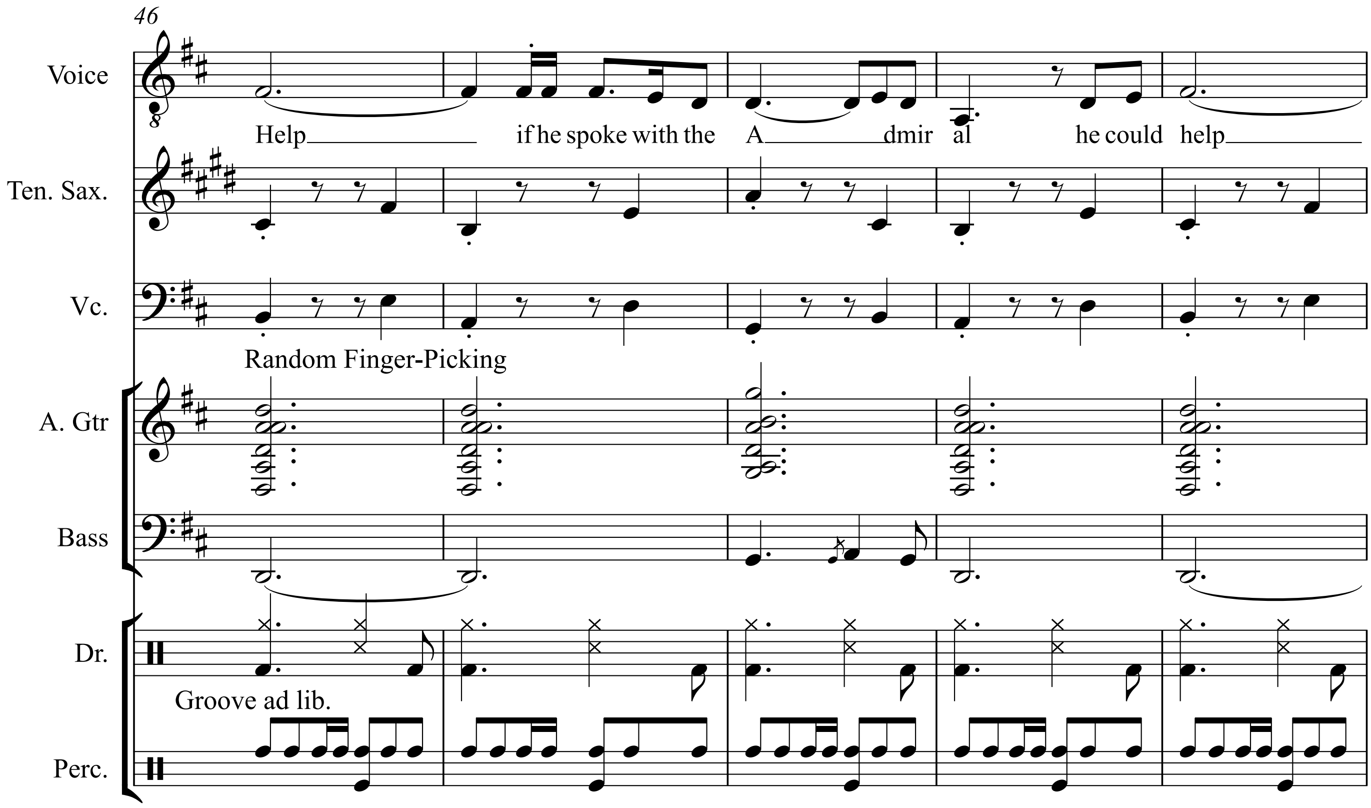

26
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
way but no' mine ...and I
P.M.
ff
ff


29
C
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
Ken it's no right for me but I ken
C

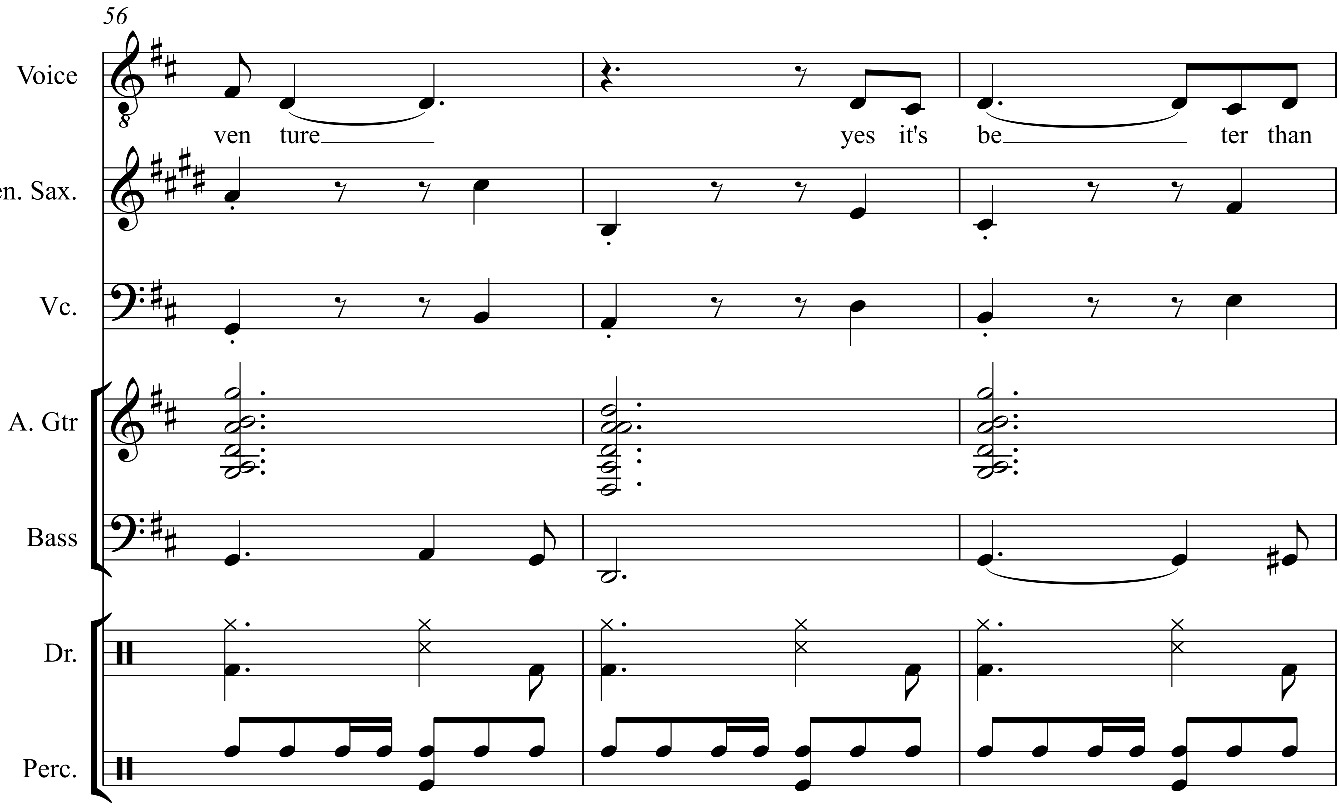

34
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
it's the way it has to be and I ken___ I'm to

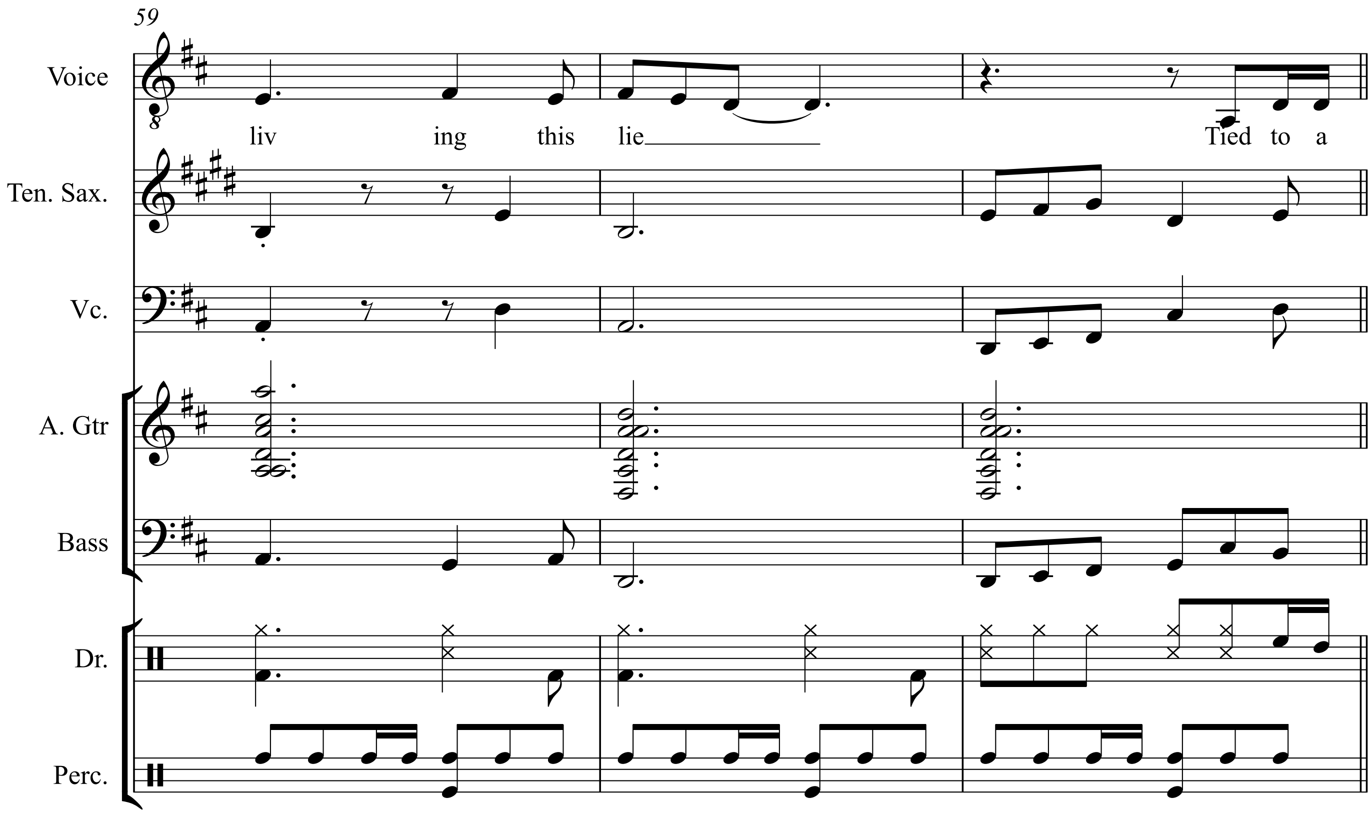

39
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
fol low my fai___ ther but I dream of being a

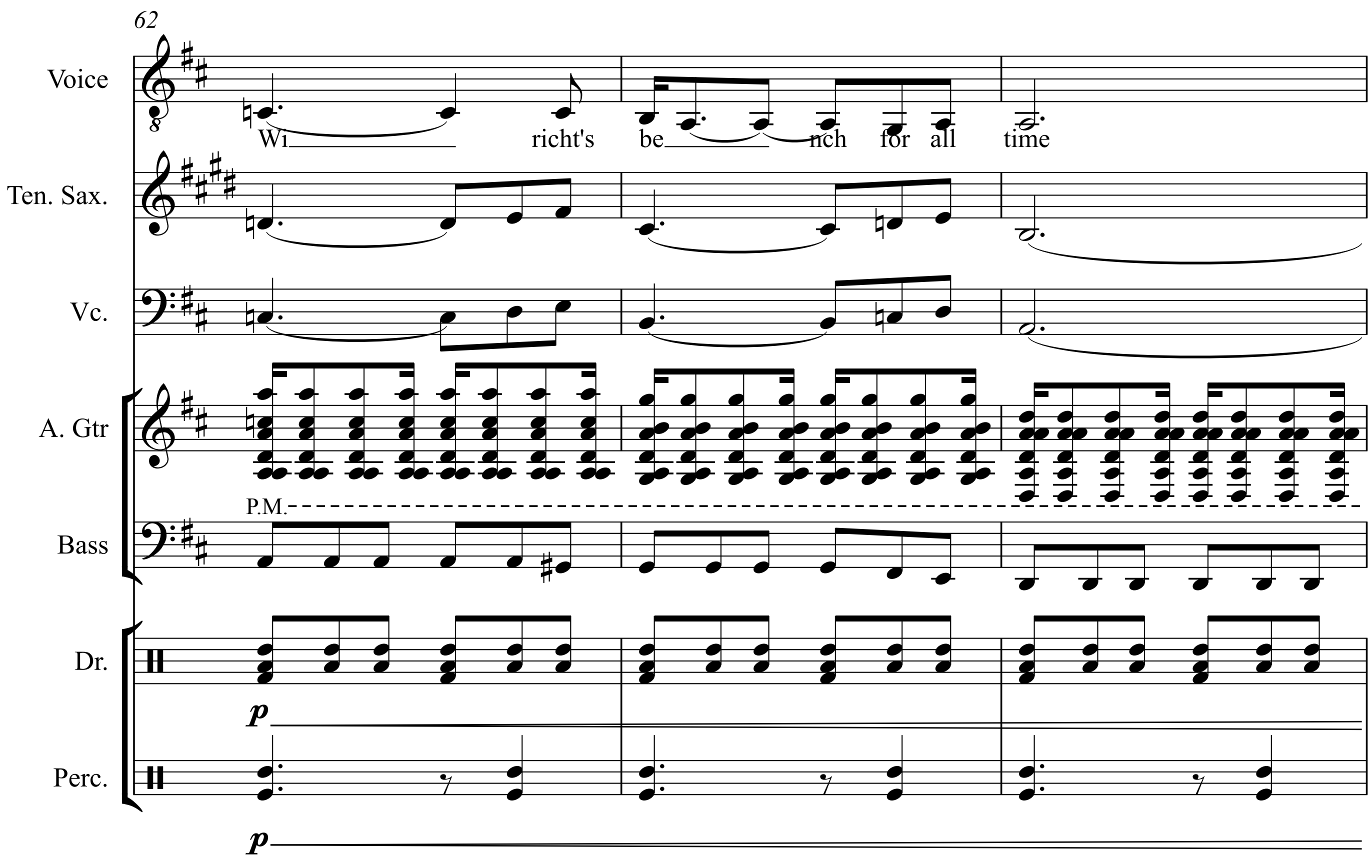

42
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
sai lor in the glo ry of the war he could


46
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
Help if he spoke with the A dmir al he could help
Random Finger-Picking
Groove ad lib.


51
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
if he ca red to try
all I want
is my chance for ad


56
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
ven ture
yes it's be
ter than


59
Voice
liv ing this lie
Tied to a
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


62
Voice
Wi richt's be nch for all time
Ten. Sax.
Vc.
A. Gtr
P.M.
Bass
Dr.
p
Perc.
p


65
Voice
that's my fai ther's
Ten. Sax.
Vc.
A. Gtr
P.M.
Bass
Dr.
Perc.
67
Voice
way but no' mine ...and I
Ten. Sax.
Vc.
A. Gtr
P.M.
Bass
Dr.
ff
Perc.
ff


70
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
Ken it's no right for me but I ken
75
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
it's the way it has to be and I ken I'm to


80
Voice
fol low my fai ther but I dream of being a
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
83
Voice
sai lor in the glo ry of the war
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


87
Guitar solo
Voice
Guitar Solo
Ten. Sax.
Guitar Solo
Vc.
Guitar Solo
A. Gtr
Guitar Solo
Bass
Dr.
Groove ad lib.
Perc.
92
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


97
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
102
Voice
Ten. Sax.
Vc.
Am
G
D
A. Gtr
Bass
Dr.
p
Perc.
p

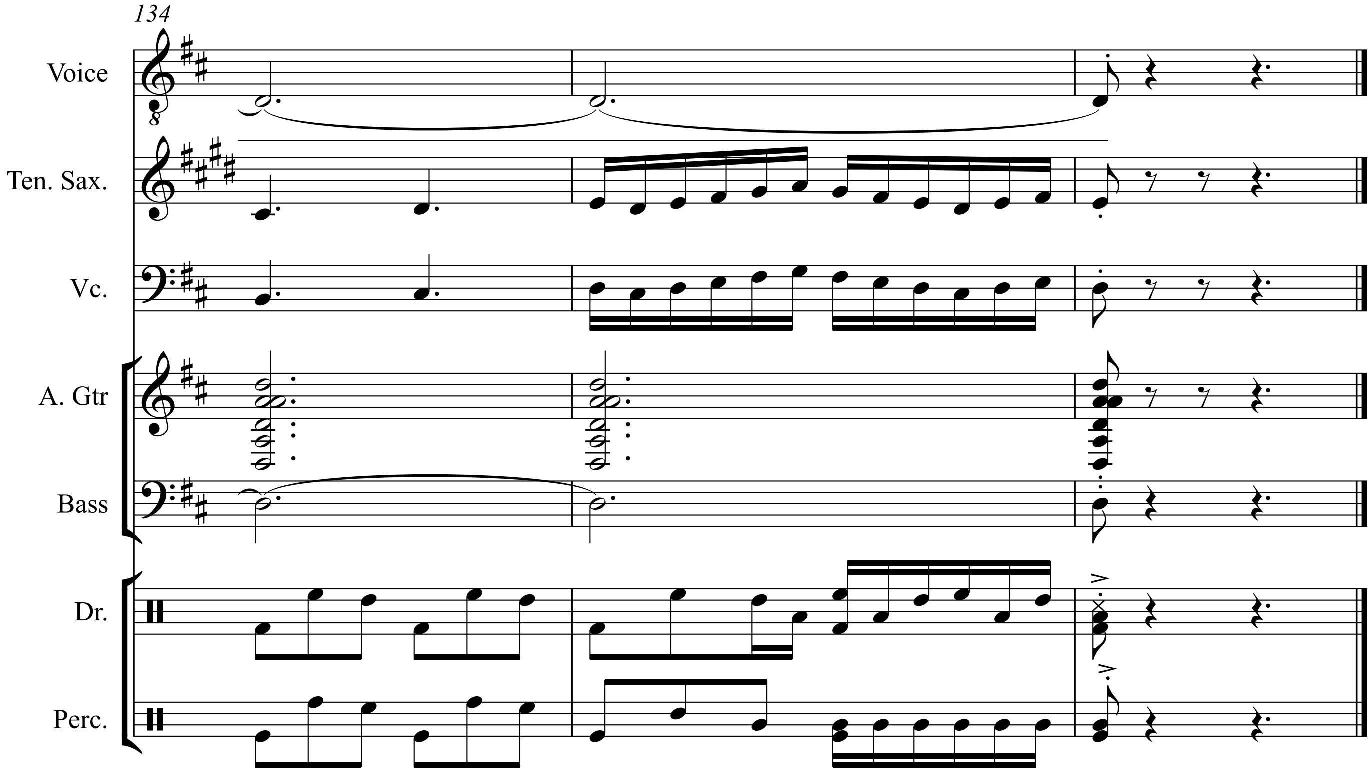

107
Voice
Ten. Sax.
Vc.
Am
G
A
A
A. Gtr
Bass
Dr.
ff
Perc.
ff


111
Voice
Ken
it's no
right for me
but I
ken
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


116
Voice
it's the way it has to be and I ken I'm to
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.
121
Voice
fol low my fai ther but I dream of being a sai lor yes I
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


126
Voice
dream of being a sai lor yes I dream of being a sai lor
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


131
Voice
in the glo ry of the war!
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.


134
Voice
Ten. Sax.
Vc.
A. Gtr
Bass
Dr.
Perc.

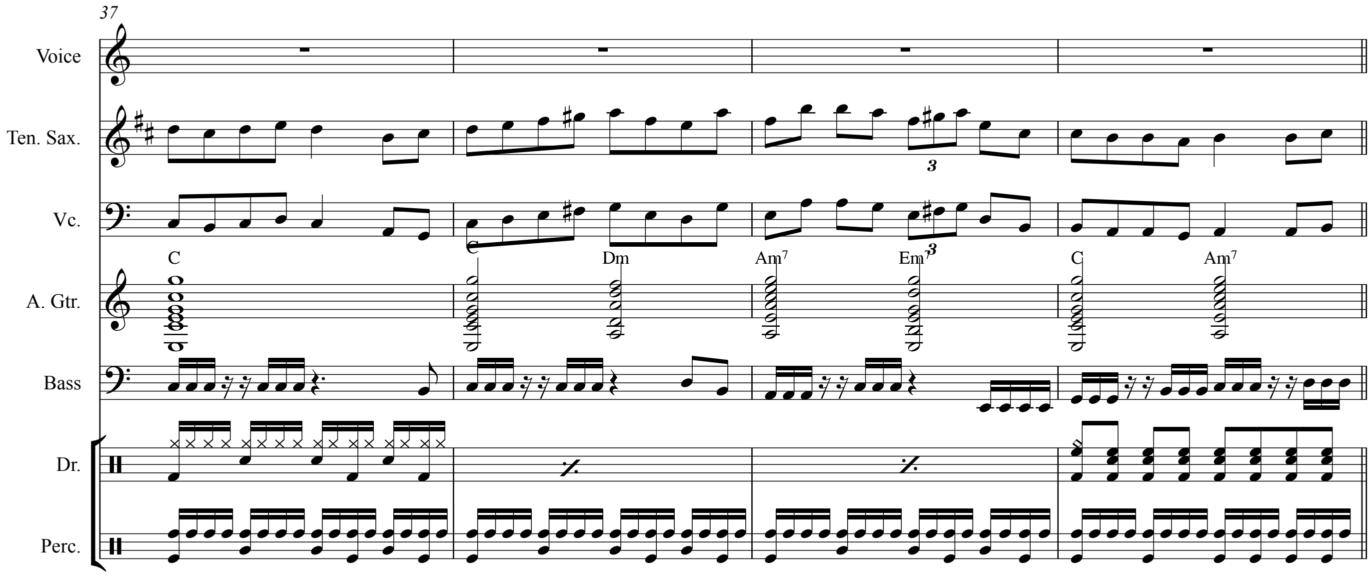
## G.3 Ceilidh

# Ceilidh

Traditional Tunes
Arranged by
Zack A. Moir


15
Voice
Ten. Sax.
Vc.
3
A. Gtr.
P.M.
Bass
Dr.
open hat...
Perc.
19
Voice
Ten. Sax.
Vc.
A. Gtr.
P.M.
Bass
Dr.
Perc.
22
Voice
Ten. Sax.
Vc.
3
A. Gtr.
P.M.
Bass
Dr.
Perc.


25
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
C
C
Dm
Am7
Em7
C
Csus4
C
C
Dm
Am7
Em7
C
Am7
3
33
C
Dm
Am7
Em7
C
Csus4


37
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
C
Dm
Am7
Em7
C
Am7
3
3


41
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
3
3
3
3


47
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
3


52
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
3
57
Dm11
Em11
D
Bm7
Em7
A7
Fill
Fill on Cajon
Fill..........
Fill on Djembe
Funky djembe groove with this bass pattern
63
D
Em7
A7
D


66
Voice
Ten. Sax.
Vc.
A. Gtr.
Bm7
Em7
A7
D
Em7
A
Bass
Dr.
Perc.
69
Voice
Ten. Sax.
Vc.
A. Gtr.
A
Bmin
A
Bass
Dr.
Perc.
72
Voice
Ten. Sax.
Vc.
A. Gtr.
Emin
D
Emin
Bass
Dr.
Perc.


75
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
D
Bmin
Emin
first time only
77
molto rall.
♩. = 55 Soul Shuffle Feel
sfz
p
ff
B♭7
Cm7
A♭7
84
A♭maj7
E♭7


91
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
cut, watch for cue
cut, watch for cue
Fm7 Gm7 A♭ma7 Gm7 E7
cut, watch for cue
cut, cue band off
95
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
102
♩ = 100
Voice
Ten. Sax.
Vc.
Solo
A. Gtr.
Bass
♩ = 100
Dr.
Close hats on 2 + 4
Perc.


108
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
114
Asus4 A Sim....
120
Should auld a-quaint-ence be for-got and ne - ver brought to mind should auld a-quaint-ence


126
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Perc.
be— for got for auld— lang syne. For auld— lang syne my dear for auld— lang syne we'll
Asus2 A
Sim...
Asus4 A
133
solo
tak a cup o' kind-ness yet for— auld lang syne.
Asus2 A
Sim ...
Asus4 Asus2
A

## G.4 Deacon


A
5. Deacon
by Zack A. Moir
Voice
Tenor Sax
pizz.
Cello
Guitar DADGAD
Bass
Drums
Am11
B°
Dm7
7
Sax.
Vc.
A. Gtr.
Dr.
12


B
17
Voice
...and thats him dead now
but I'm no go-nae fret
Sax.
Vc.
A. Gtr.
Bass
B
Dr.
24
...and I'll no' fo - low
the ex-amp-les that he set
gliss.
arco
gliss.
sfz
gliss.
sfz
31
for i see it this way
that this
3
3
3
3


38
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
is my own chance
to use my fai_ther's croan -
gliss.
sfz
44
ies
for the re - spect that I de - mand.
C
49
pizz.
Am11
B°
Dm7
Strumming sim.
3


56
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
Am11
B°
Dm7
60
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
Am11
B°
Dm7
65
D
Voice
now I'm the Dea - con the head of this fine trade
Sax.
Vc.
A. Gtr.
Bass
D
Dr.


72
Voice
it's up to me now to really spread my name
Sax.
gliss.
sfz
arco
Vc.
A. Gtr.
Bass
Dr.
79
for I see it this way that i
3
86
just can not fail
I'm ev-ery bit as good


92
Voice
as
that fel low Mis ter Chip en dale.
Sax.
Vc.
A. Gtr.
Bass
Dr.
97
E
(arco)
Am11
B°
Dm7
Am11
B°
Dm7
104
Am11
B°
Dm7


108
Voice
Sax.
Vc.
Am11
B°
Dm7
A. Gtr.
Bass
Dr.
F
113
Voice
Sax.
Vc.
A. Gtr.
Bass
F
Dr.
117
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.

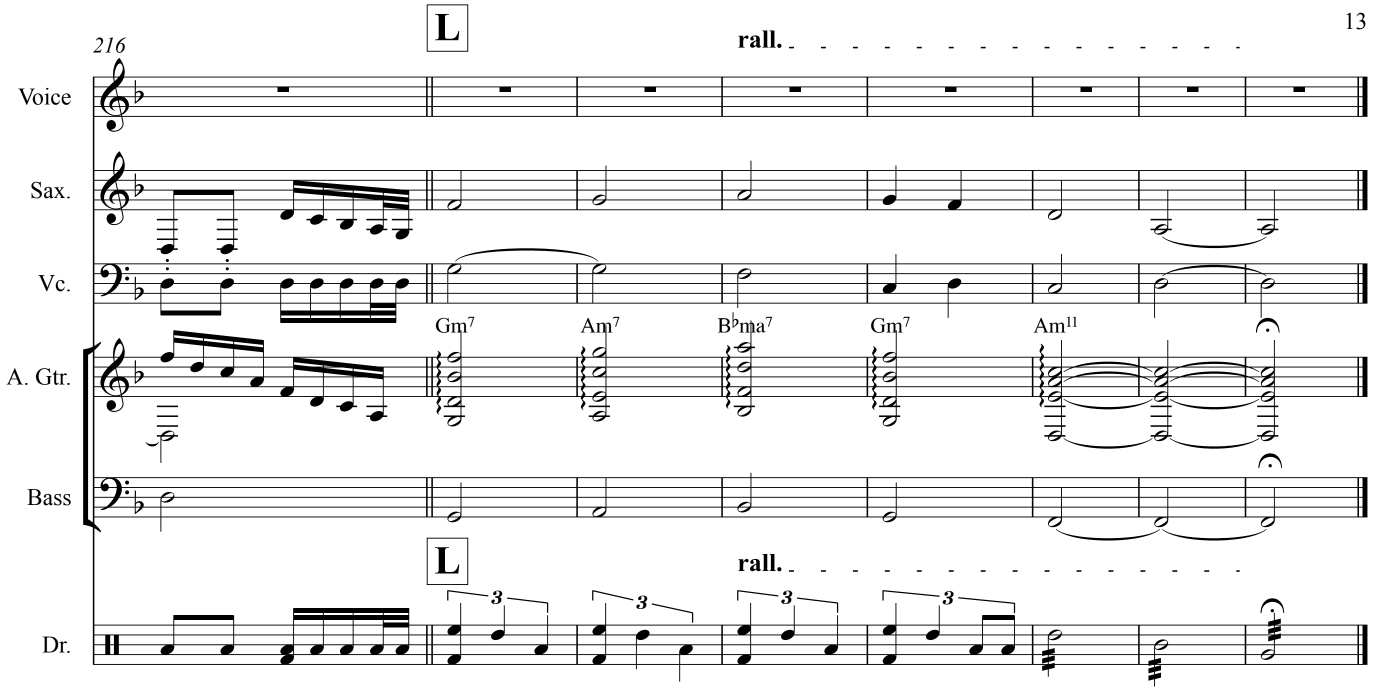

126
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
tr
134
G
Voice
Sax.
Vc.
A. Gtr.
Bass
G
Dr.
140
Voice
Sax.
Vc.
A. Gtr.
gliss.
Bass
Dr.


147
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
H
153
Sax Solo
Dm7
160
gliss.


165
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
169
I
pizz.
Am11
B°
Dm7
Strumming sim.
176


180
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
Am11
B°
Dm7
J
185
Now things are chan - ging and I can rea lly see
K
192
They way the peo ple have come to count on me
gliss.
arco
sfz


199
Voice
Sax.
Vc.
A. Gtr.
Bass
Dr.
for i see it this way
That they
206
dont have a clue
but I must keep pre ten
gliss.
sfz
212
ding
for they would hang me if they knew
sfz


216
L
rall.
Voice
Sax.
Vc.
Gm7
Am7
B♭ma7
Gm7
Am11
A. Gtr.
Bass
L
rall.
3
Dr.

## G.5 If I'm Honest

# 5. If I'm Honest...

by Zack A. Moir

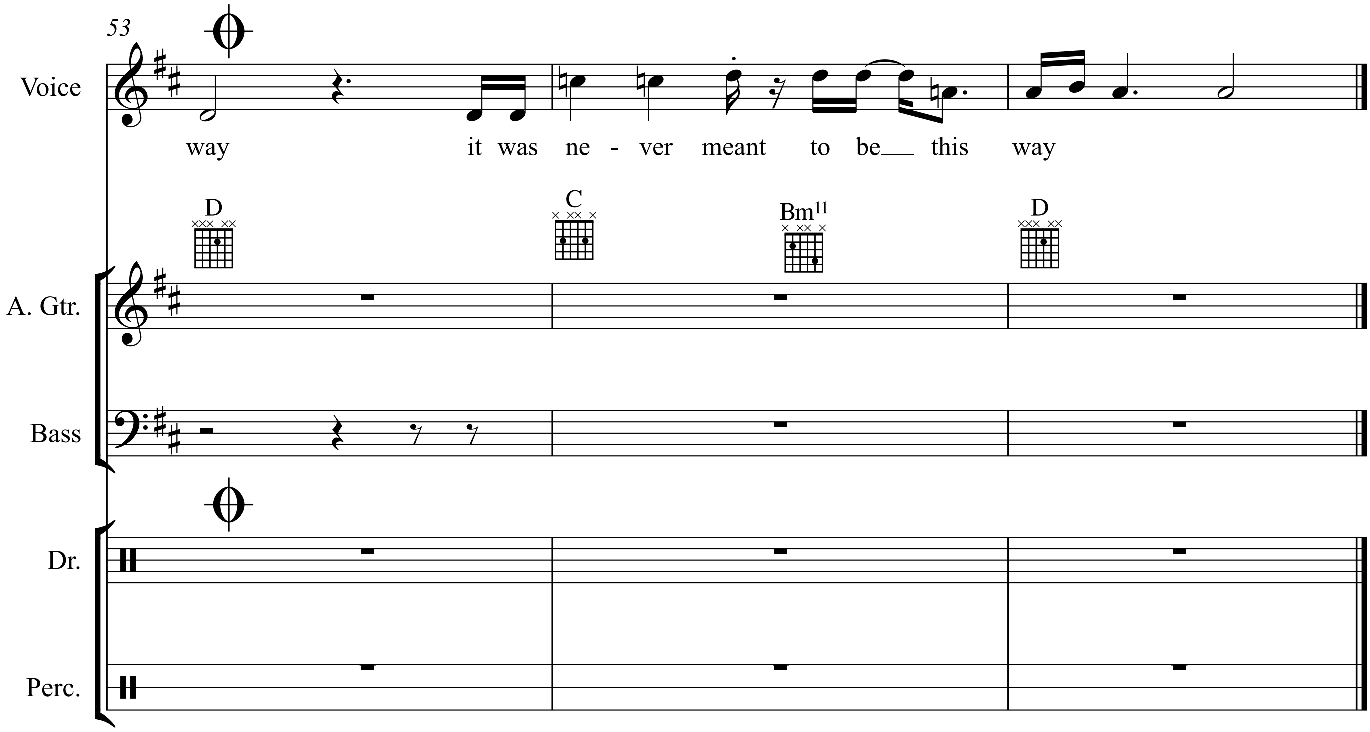

11
Voice
told you why I do it, if I told you why I steal would you
C♯m
Bm11
Em
Em(add9)
A. Gtr.
Bass
Dr.
Perc.
15
lis - ten when I say it was ne - ver meant to be_ this way
D
Bm11
C
Bm11
D
19
♩ = 120
This is not just how it seems
♩ = 120


23
Voice
This is just a case of need
A. Gtr.
Bass
Dr.
Perc.
27
Voice
I don't do this for the fun
A. Gtr.
Bass
Dr.
Perc.
31
Voice
this is just who I've be - come
A. Gtr.
Bass
Dr.
Perc.


34
Voice
A. Gtr.
Bass
Dr.
Perc.
36
I
ne ver want ed a - ny of this
Strumming ad lib.
39
This is not what I had


42
Voice
planned
I ne - ver dreamed
A. Gtr.
Bass
Dr.
Perc.
45
Voice
I would be - come the sin - ner I've turned in to.
A. Gtr.
Bass
Dr.
Perc.
48
Voice
Is my soul for - ev - er
A. Gtr.
Bass
Dr.
Perc.


50
Voice
rall.
damned
I'm a
If I'm
A. Gtr.
Bass
rall.
Dr.
Perc.


53
Voice
way
it was ne - ver meant to be this way
D
C
Bm11
D
A. Gtr.
Bass
Dr.
Perc.

## G.6 Thieves and Rogues

# 6. Thievs and Rogues

by Zack A. Moir

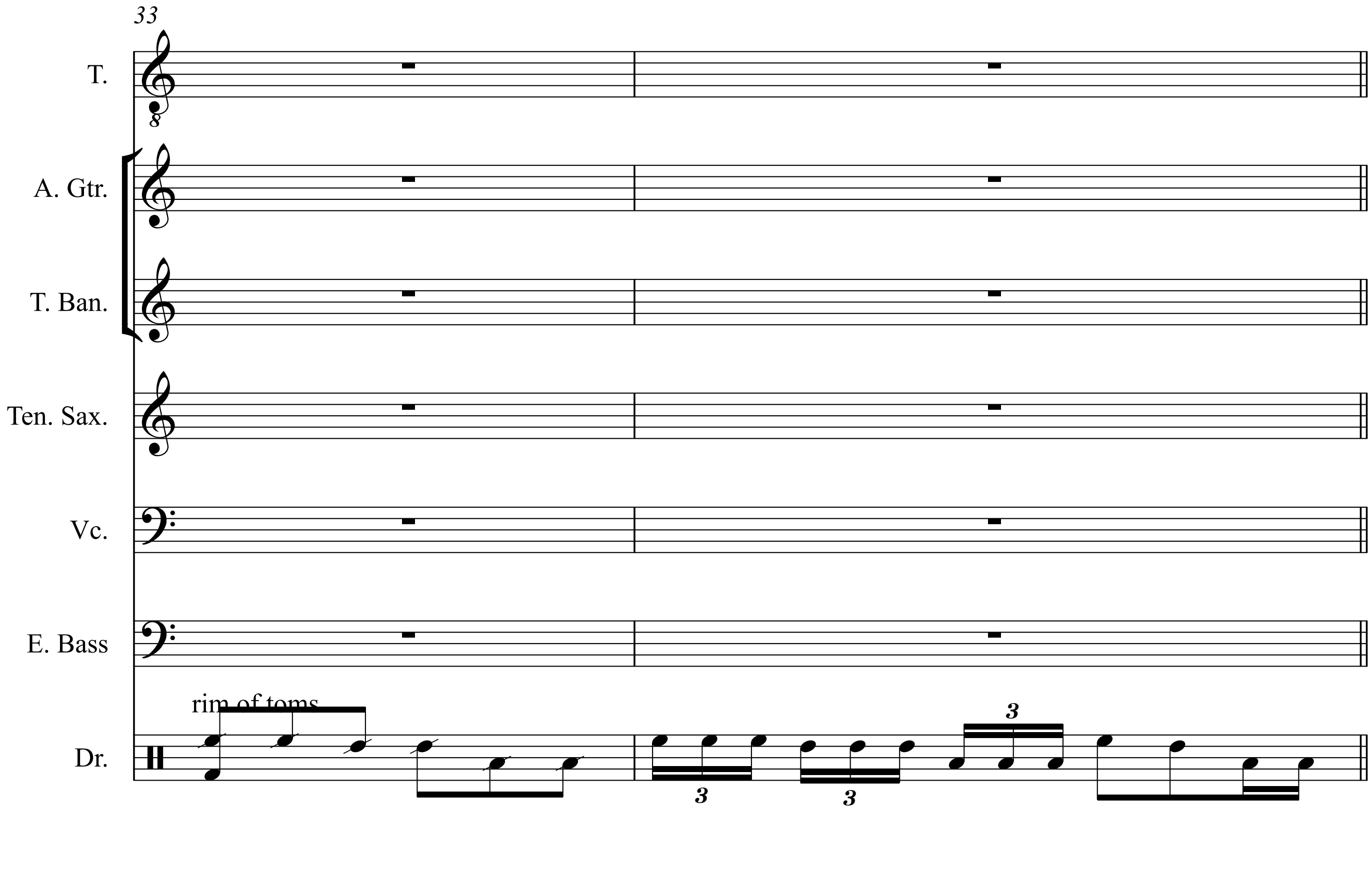

13
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
B♭ma7
Cma7
Gm6
B♭ma7
Cma7


17
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
or is it a matt er of thievs and rogues who're stripp ing the
E°
Bm
E°

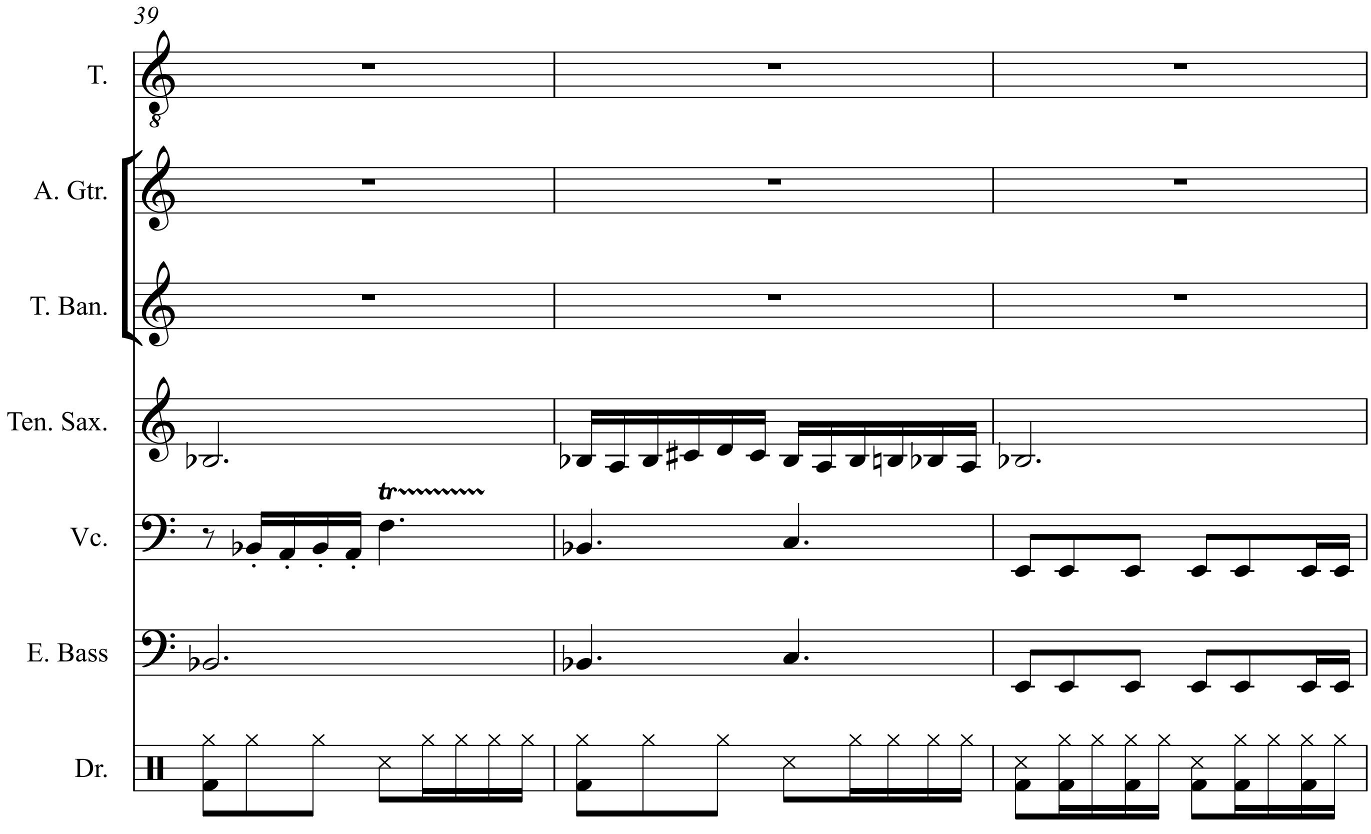

22
T.
flesh from this town or was it a matt er of
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.

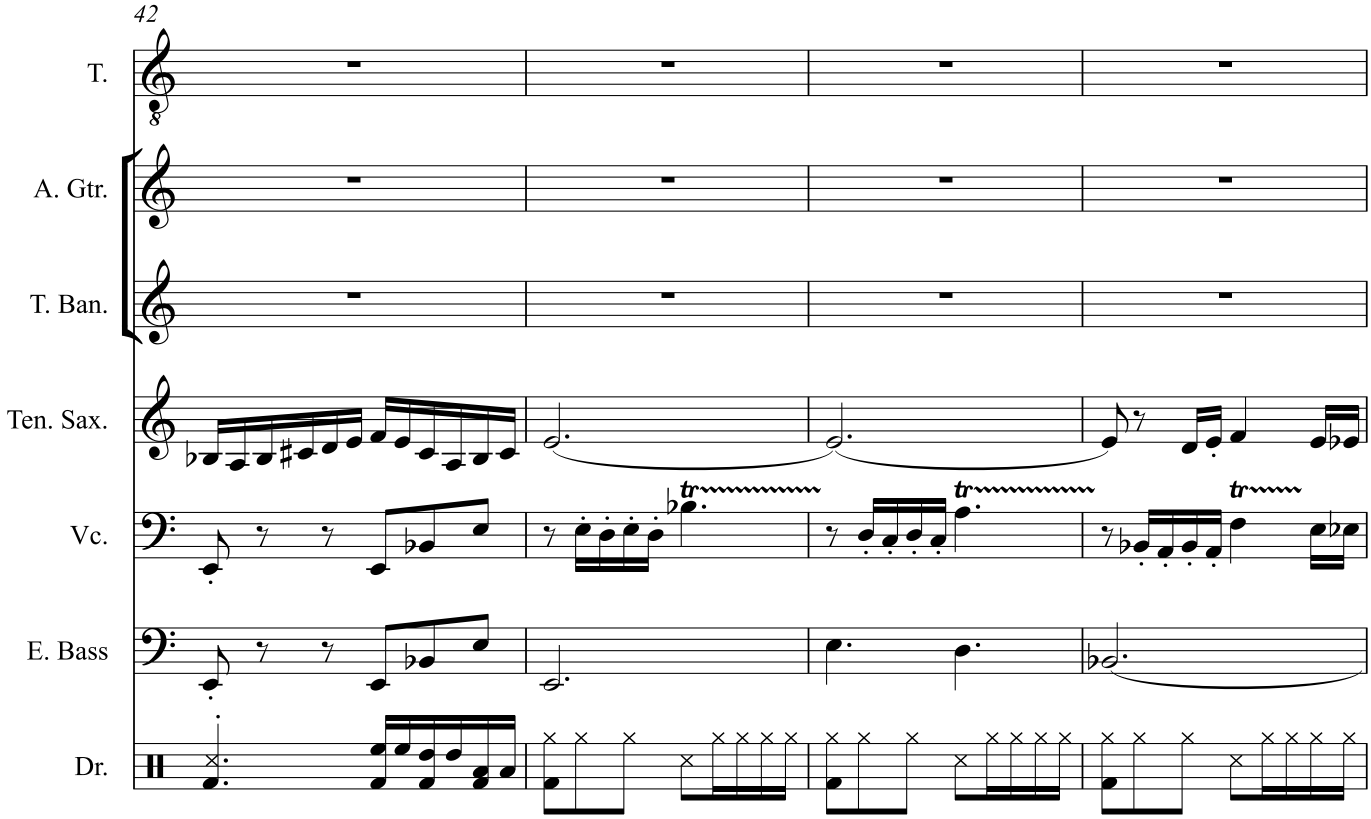

27
T.
cold dark souls who haunt our
A. Gtr.
Bm
Bm/C
T. Ban.
Bm
Bm/C
Ten. Sax.
Vc.
E. Bass
Dr.


30
T.
nights and can't be found an y where
A. Gtr.
Bm
C♯m/D
C♯m
T. Ban.
Bm
C♯m/D
C♯m
Ten. Sax.
Vc.
E. Bass
Dr.


33
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
rim of toms
3


35
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
tr
tr
tr


39
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
tr


42
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
tr
tr
tr


46
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
tr


50
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
E°
now who can be
E°
52
blamed for these phan - tom crimes
Bm
Bm


55
T.
E°when we can't find one sin gle man?
when no earth-ly
A. Gtr.
E°
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
60
T.
bo- dies could leave no trace
Bm
we
Bm/C
must
be
A. Gtr.
Bm
Bm/C
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.


64
T.
leive it's the work of the damned e - vil souls
Bm
C♯m/D
C♯m
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
Solo -
Very freely, as if improvised.
67
pizz.
arco
sfz
72
77
80
82
85


89
T.
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.
a tempo
arco
E°
or is it a
E°
93
matt er of thievs and rogues
who're stripp ing the flesh from this
Bm
E°
Bm
E°


98
T.
town
or was it a matt er
of cold dark souls
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.


103
T.
who haunt our nights and
Bm
Bm/C
Bm
A. Gtr.
Bm
Bm/C
Bm
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.


106
T.
can't
be
found
an y where
C♯m/D
C♯m
E°
A. Gtr.
T. Ban.
Ten. Sax.
Vc.
E. Bass
Dr.

## G.7 These Fools

# 7. These Fools Will Never Know

by Zack A. Moir


11
Voice
the sweet-est hour i e'r did spend were spent a mang the lass-ies o' Green Grow the ra-shes o'
Ten. Sax.
Vc.
C Bm C Em G
A. Gtr.
Bass
Dr.
14
Voice
Green grow the ra-shes o' the sweet-est hour i e'r did spend were spent a mang the lass-ies o'
Ten. Sax.
Vc.
Bm C Bm C Em
A. Gtr.
Bass
Dr.
17
Voice
Green Grow the ra-shes o' Green grow the ra-shes o' the sweet-est hour i e'r did spend
Ten. Sax.
Vc.
G Bm C Bm
A. Gtr.
Bass
Dr.


A
♩ = 120
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
were spent a mang the lass-ies o'
These fools will ne ver know,theythink it's ghosts or
C
Em
Left hand mute for percussive effect
Rhythmic Strumming
G
Bm
C
deils or witch es They'll nev er con tem plate that it's some one like me no, These fools will ne ver know,they
D G Bm C G G Bm
think it's ghosts or deils or witch es. They'll nev er con tem plate that it's some one like me.
C Bm G Bm D C C


39
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
C
C
D
D
Bm11
G
P.M.
45
C
Dsus4
Bm11
G
Dsus4
G
Bm11
P.M.
49
C
Dsus4
G
Bm11
Dsus4
C
Bm11
Dsus4
G
Bm11
P.M.


53
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
C
Dsus4
G
Bm11
Dsus4
G
Bm11
P.M.
57
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
C
Dsus4
G
Bm11
Dsus4
C
Bm11
Dsus4
G
Bm11
P.M.
61
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
C
Dsus4
G
Bm11
Dsus4
G
Bm11
P.M.


65
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
C
Dsus4
G
Bm11
Dsus4
C
Bm11
Dsus4
P.M.
68
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
G
Bm11
C
Dsus4
G
Bm11
P.M.
71
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Dsus4
G
Bm11
P.M.


73
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
C
Dsus4
G
Bm11
Dsus4
C
Bm11
Dsus4
P.M.
76
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Em9
F♯m11
Am9
Bm(♭13)
80
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
Em9
F♯m11
Am9
Bm(♭13)


84
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
87
G
D
G
91
D
G
G


95
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
These fools will ne-ver know
these fools will ne-ver know
D
C
Rhythmic Strumming
Bm
98
they know not now and will not heed
the se-cret dou - ble life I lead
I'm get - ting of with it
C
Bm
C
Em
G
101
they know not who it is
I'll fund my life of girls and drink
by stea-ling from the peo-ple o
Bm
C
Bm
C
Em


104
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
GreenGrow the ra-shes o'
Green grow the ra-shes o'
the sweet-est hour i e'r did spend
G
Bm
C
Bm
107
were spent a mang the lass-ies o'
Green Grow the ra-shes o'
Green grow the ra-shes o'
C
Em
G
Bm
110
the sweet-est hour i e'r did spend
were spent a mang the lass-ies o'
Green Grow the ra-shes o'
C
Bm
C
Em
G


113
molto rit.
Voice
Green grow the ra-shes o' the sweet-est hour i e'r did spend were spent a mang the lass-ies o'
Ten. Sax.
Vc.
Bm C Bm C
A. Gtr.
Bass
molto rit.
Dr.
116
A tempo
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
A tempo
Dr.
120
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.


124
Voice
Ten. Sax.
Vc.
A. Gtr.
G
Bm
C
D
G
Bm
D
C
Bm
D
P.M.
Bass
Dr.


128
Voice
Ten. Sax.
subito p
pizz.
Vc.
subito p
A. Gtr.
subito p
P.M.
Bass
subito p
Dr.
subito p

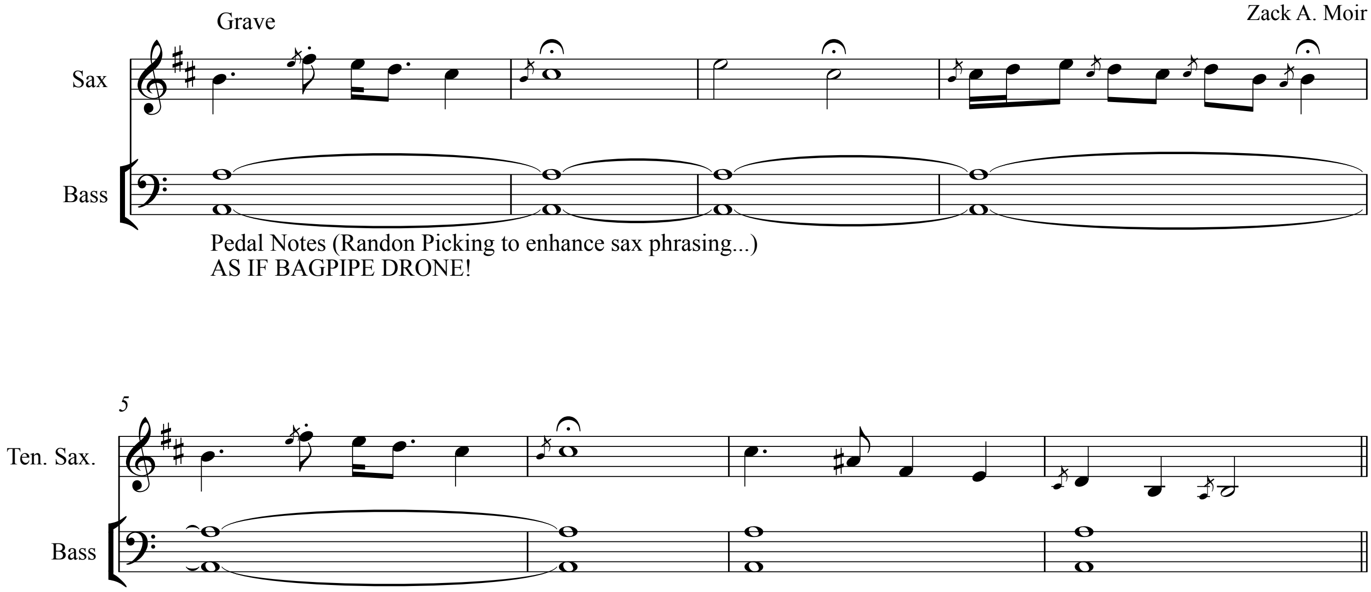

133
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
ff
P.M.
138
These fools will ne ver know, they think it's ghosts or deils or witch es They'll nev er con tem plate that
G
Bm
C
D
Alla Marcia
144
accel.
it's some one like me no, These fools will ne ver know, they think it's ghosts or deils or witch es.


150
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
They'll nev er con tem plate that it's some one like me Green Grow the ra-shes o'
G Bm D G
P.M.
156
Greengrow the ra-shes o' the sweet-est hour i e'r did spend were spent a mang the
Bm C Bm C
161
lass-ies o' some one like me it's some one like me it's me!
Em C C C D D G

## G.8 Turning King's Evidence

# Turning Kings Evidence

by
Zack A. Moir




9
Voice
Just a no r mal job, No more dan ger ous than it ev er is
Am⁹ Dm⁶ Dm⁹ Am⁹
A. Gtr.
13
Voice
How did th ey find out, where to find us this march night?
Am⁹ Dm⁶ E Am⁹
A. Gtr.
17
Voice
No - one cou-ld have known where we pla nned to strike on that spring night.
Vc.
Am⁹ Dm⁶ Dm⁹ Am⁹
A. Gtr.
21
Voice
How could they have known where we would be and what time?
Ten. Sax.
Vc.
Am⁹ Dm⁶ E Am⁹
A. Gtr.
25
Ten. Sax.
Vc.
Am(♭13) Em
A. Gtr.
Bass
Dr.


29
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
B♭
Bm
Em
Am11
3
33
Voice
Just a no r mal job,
No more
p
Am9
Dm6
Dm9
36
dan ger ous than it oft en is
How did th ey find out,
were to find us
Am9
Am9
Dm6
E

40
Voice
this march night? Just a no r mal job,
Ten. Sax.
Vc.
Am⁹
Dm⁶
A. Gtr.
Bass
Dr.
43
Voice
No more dan ger ous than it ev er is How will th is turn
Ten. Sax.
Vc.
Dm⁶
Am⁹
Am⁹
A. Gtr.
Bass
Dr.
46
Voice
out, have we come to meet our match?
Ten. Sax.
Vc.
Dm⁶
E
Am⁹
A. Gtr.
Bass
Dr.


49
Voice
There must be a clype a - mongst us, for On - ly we four
We'll be caught and put on tri - al and if found guil - ty
Ten. Sax.
Vc.
Cmaj♯9
E♭m
A. Gtr.
Bass
Almost Tribal - MENACING!
Actual toms doesn't matter - just this feel!!
Dr.
52
knew the plan
We can't flee for
sent to hang
But the one who
Em
54
we're sur - roun - ed and we're out - num - bered
ten to one.
was the trait - or will be ex - cused if
Gm7
1.


57
2.
Voice
he turns the king's ev id ence
Ains - ley was the wretch - ed trai - tor and
Ten. Sax.
Vc.
Cmaj♯9
E♭m
A. Gtr.
Bass
Dr.
61
sold the gang for his own skin
He in - formed the
E♭m
Em
64
ci - ty sold - iers and was re - prieved for he turned the king's ev id ence
G7


68
♩. = 30
Voice
Ten. Sax.
Freely and mourning
Vc.
A. Gtr.
Bass
♩. = 30
Dr.
75
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
80
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.


85
molto rall.
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
molto rall.
Dr.
90
Freely
Ten. Sax.
Bass
Random Atmospheric beats on toms
Dr.
94
Ten. Sax.
rall.
Vc.
Cm11
A. Gtr.
Bass
Dr.
rall.

## G.9 To Hang by the Neck

# To Hang by the Neck...

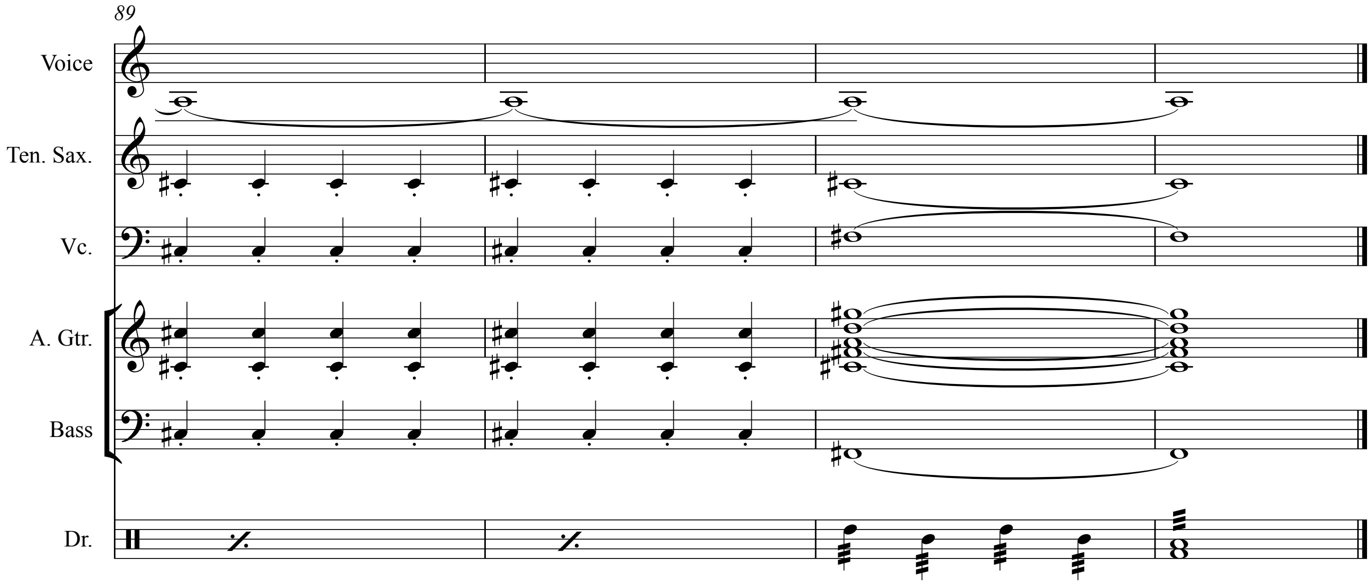
By
Zack A. Moir


33
Ten. Sax.
3
Vc.
A. Gtr.
Bass
Dr.
40
Ten. Sax.
Vc.
Bass
Dr.
45
Ten. Sax.
Vc.
Bass
Dr.
48
Voice
found
Ten. Sax.
Vc.
Bass
Dr.


52
Voice
guil ty of these crimes I'm to hang by the neck
Vc.
A. Gtr.
Bass
57
Voice
from the end of a line They wont get their man for I have a
Vc.
A. Gtr.
Bass
3
62
Voice
Plan Those Gall ows they loom
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.


66
Voice
large i'll no' fret ab out them I'v a sur geon on
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
70
Voice
hand Paid to save my life when the hang-man ha s
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
74
Voice
gone Then I'll flee from here to my fr ee
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.


78
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.
dom
They wont get this man for I have a
82
plan
I wont let them win for I have a plan
86
They will not suc seed They wont get this man


89
Voice
Ten. Sax.
Vc.
A. Gtr.
Bass
Dr.

# Appendix H

# Deacon CD/DVD Pack

*See enclosed CD/DVD package for this appendix.*